

TENS

The Advanced User's Guide



***By Dr Gordon Gadsby
and Michael Flowerdew***

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J Gordon Gadsby

BA RGN RMN DipN MISBM DHP DHS PhD

Michael Flowerdew

BSc MSc MIBiol PhD

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*THIS SUPPLEMENT HAS BEEN PREPARED AS A
SEPARATE SECTION SO THAT YOU PRINT OUT THE
IMAGES OF ELECTRODE PLACEMENTS*



*Published and distributed by Body Clock Health Care Ltd
208 George Lane South Woodford
London E18 1AD UK
Telephone +44 (0)20 8532 9595
email sales@bodyclock.co.uk*

www.bodyclock.co.uk ➤

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About the authors

Dr Michael Flowerdew gained a PhD in population genetics at the University of Wales and carried out research contracts at the University College of North Wales, Bangor UK, on marine biology projects for a number of years. In a dramatic change of career, he became increasingly interested in acupuncture and electrical therapies and was involved in the production of training course in modern approaches to acupuncture for medical practitioners, both in the UK and on the Continent. Currently, he lives in Suffolk with his family where he has practised electroacupuncture for over 16 years.

As well as producing teaching material, he has been involved in the development of electrical treatments for the treatment of heroin and benzodiazepine addiction and still has links with a group in Liverpool called Drug Free who use these techniques. For a number of years he worked with Equinox International to develop electrical procedures for dental analgesia. Another area of special interest is the use of electrical treatments during pregnancy.

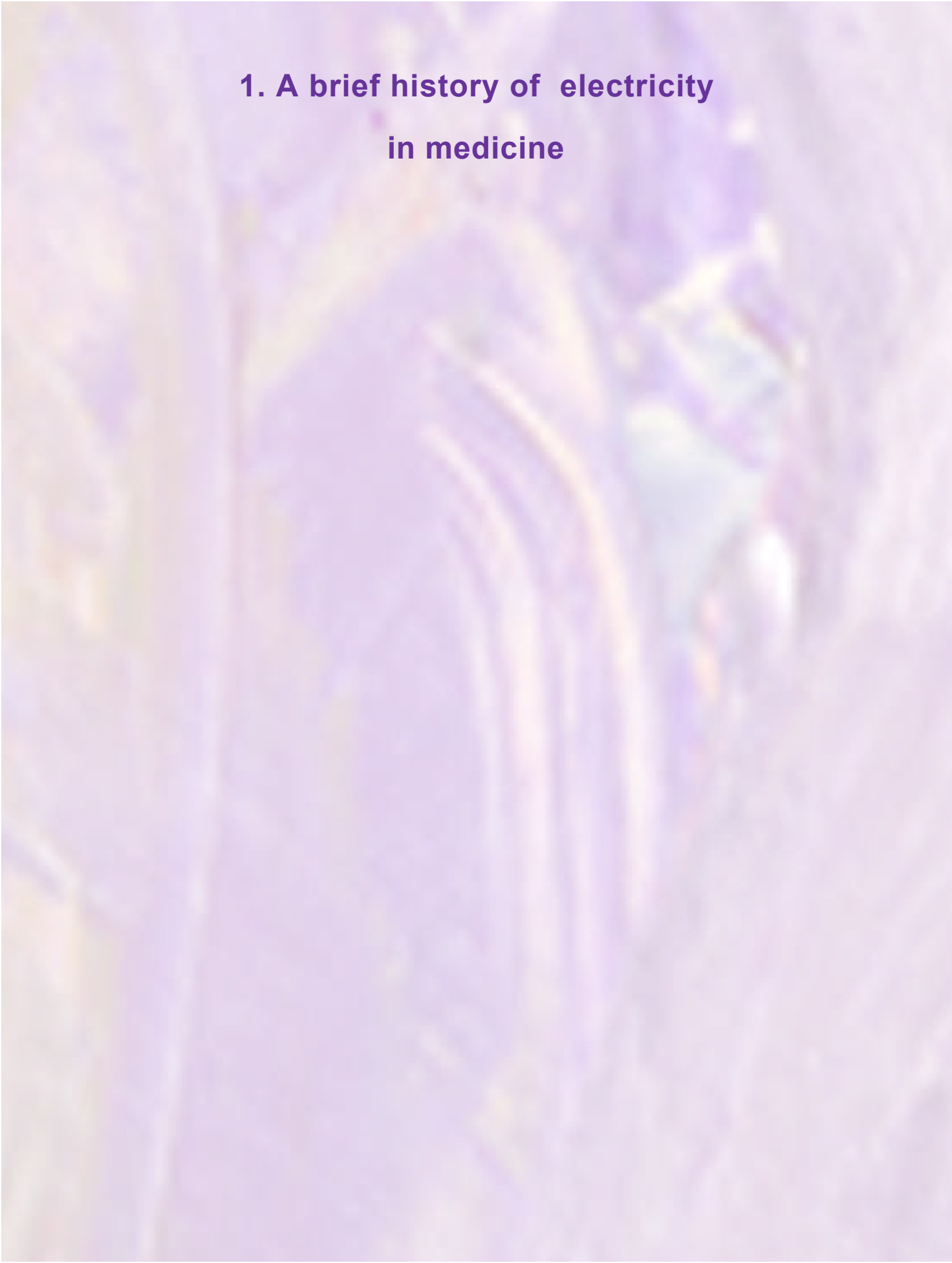
Dr Gordon Gadsby is a leading clinical specialist in electroacupuncture acupuncture and transcutaneous electric nerve stimulation, who now practices in the private health care sector, following a successful twenty eight year career in psychiatric and general NHS hospital nursing. He is currently chief executive and a senior tutor for the Society of Electrotherapists, which developed from the International Society of Biophysical Medicine.

He has practised in Leicester, UK for the last twenty years as an electroacupuncturist, hypnotherapist and TENS specialist. He has a degree in Health Studies and a doctorate in electroanalgesia from the De Montfort University, Leicester. As part of his PhD, Dr Gadsby researched

the historical and contemporary developments of electrical analgesia and his thesis included a systematic review and meta-analysis of the electrical treatment of chronic low back pain, using transcutaneous electrical nerve stimulation and acupuncture-like transcutaneous electrical nerve stimulation, within the framework of the Cochrane Collaboration.

MWF and JGG have been colleagues for a number of years and are founder members of the Society of Electrotherapists. They have worked together previously to produce a meta-analysis on the use of TENS for the treatment of low back pain as part of the Cochrane Collaboration.

1. A brief history of electricity in medicine



1. A BRIEF HISTORY OF THE USE OF ELECTRICITY AS MEDICINE.

It is hard to imagine electricity as a source of wonder and mystery; we tend to forget that the age of electricity is only 100 or so years old and extensive distribution networks are recent developments but which we now take for granted. For example, the development of electric tramways and the underground railway made large electricity generation an economic proposition in London for the first time towards the end of the 19th century. Extensive distribution and use of electricity has brought with it questions about possible detrimental effects for health but using electricity to maintain or restore good health goes back more than 2000 years.

For over 10,000 years, body ornaments made from 'animated minerals' such as amber and magnetite have been worn to prevent or cure a wide range of illnesses. Generating static electricity by rubbing amber was known to the ancient Greeks and was described by Thales around 400BC and the Greek for amber has entered the English language as 'electron' to describe the stable elementary particle which carries electricity in solids. A natural source of electricity is thunderstorms. There were a large number of thunderstorm deities throughout the world but they were concerned more with retribution than healing.

Evidence for man-made electricity sources from as early as 250BC have been found in [Iraq](#)¹. Excavations near Baghdad in the 1930s revealed artifacts which have the appearance of batteries with copper cylinders in iron vessels. Wilhelm König, head of the Iraqi Museum Laboratory at the time, suggested that these devices could be wired in series and would generate enough electricity for electroplating and may have been used for healing. Modern replicas have produced 0.5V using vinegar, wine or copper sulphate solution as electrolytes.

The medicinal use of electricity using natural power sources was first recorded in the 1st century AD around the Mediterranean Sea and involved the discharges from species of electric fish, the torpedo,

electric eel and some catfish, which are capable of emitting up to 350V. The Nile catfish is depicted in Egyptian tombs as early as 2750BC. Hippocrates established a medical school in Athens in the 5th century BC and is alleged to have considered the medicinal properties of the torpedo fish but seems to have been more concerned with its nutritional as opposed to its electrical **qualities**². There are other Greek and Roman records about electric fish; Plato, Aristotle, Pliny, Plutarch, Celsius and Obibasius all described the unpleasant shocks from the torpedo fish and electric eel. Eating parts of electric fish have long been advocated as a folk cure for various illnesses. Scribonius Largus, a Roman physician working around 50AD is the first to have described medicinal uses for electric fish species to treat headaches and gout. Live torpedo fish were applied to wet feet or head and the shock applied until the area became numb. Around this time, the Greek physician, surgeon and pharmacist Pedanius Dioscorides advocated the electric fish treatment for haemorrhoids and anal prolapse. Galen extended the range of treatments to include melancholia, epilepsy, migraine and joint pains. The medicinal use of electric fish species continued through the centuries in North Africa, India, Arabia and around the Mediterranean and there are records of European doctors using the treatment for rheumatism as late as 1850 in **Guiana**³.

The use of electricity for technological and medicinal uses went through three major stages of development - the generation of static electricity, direct current generators and finally alternating current generators. These developments would not have realised their full potential without the eventual means to measure and control the production of the electrical current. The founder of electromagnetism - the First Electrician - was **William Gilbert** (1540-1603), physician to Elizabeth I and James I. His work on friction used rudimentary electrostatic induction machines producing a continuous separation of electric charge. He experimented with lodestones and developed the gold-leaf electroscope to detect and measure electric fields. There is no evidence that he used electricity therapeutically; this development had to wait until reliable means of generation and storing electrical energy were developed but Gilbert's induction machines were the archetype

for generators for the next two centuries. Various devices were developed to generate static electricity by rotating balls of sulphur or glass against the hand.

By the middle of the 1600s, a German engineer, physicist and natural philosopher, Otto von Guericke extended Gilbert's studies into static electricity generating large discharges of static due to the friction from rotating balls of sulphur held against the hand. The first practical device using rotating glass discs was built in 1768 by [Jesse Ramsden](#) (1735-1800) and in 1744 the first accounts of the medical use of induced static electricity began to appear in Germany. Christian Gottlieb Kratzenstein initially treated himself and found that his sleep improved but claimed major successes in treating [paralysis](#)⁴. Contemporaneously, the American statesman [Benjamin Franklin](#) was flying his kite and carrying out pioneering experiments with electricity even selling his printing business interests to fund his work. He treated paralysis too but warned against exaggerated claims for the new therapy. Much of Franklin's contribution to the understanding of electricity was theoretical but he showed electricity to be omnipresent, he expanded on the concepts of polarity and helped remove fear and superstition surrounding this new fangled phenomenon opening the way to scientific investigation. His name has been used as an eponym for static electricity, which is often referred to as franklinism, and even the pragmatist and sceptic with regard to medicine wrote "God heals and the doctor takes the fee".

The next major development was the means to store electric charge. As we have already mentioned, there is some archæological evidence of artifacts which could be batteries from around 250BC in [Iraq](#)¹. Strictly speaking, batteries do not store electricity but chemical energy which can be converted. However, the Leyden jar, named after the town where it was first developed, is generally recognised as the first device to store electric charge - a capacitor. Attributed independently to van Masschenbroek and von Kleist in the mid-1750s, the original Leyden jar consisted of a glass phial filled with water into which an electrode was dipped; the other conductor was the operator's hand holding the jar.

The jar was charged from an electrostatic generator and was capable of giving only one discharge or shock and would then have to be recharged. Initially, the apparatus was used for amusement but a charged Leyden jar could deliver a potent but unquantifiable stimulus. The means to deliver a measurable stimulus had to wait until the invention of the electrochemical cell or battery by Alessandro Volta in 1800 and the potentiometer by Sir Charles Wheatstone in 1843 which allowed for sensitive control.

Despite the paucity of basic information about the parameters of stimulation provided by the Leyden jar, the therapeutic potential proved very attractive and armed with an efficient electrostatic generator and jar, medical practitioners and charlatans alike set to working treating paralysis, stones, sciatica, angina pectoris, strokes, epileptic fits and a host of other problems. The first book on medical use for electricity was written by Johann Krueger in 1745 and by 1789, 70 medical uses had been described⁵ and 26 relevant papers had been published in the Journal du Medicine. John Wesley (1703-91), a founder of Methodism was an ardent advocate of electrotherapeutics - "I doubt not but more nervous disorders would be cured in one year by this single remedy than the whole of the English Materia Medica will cure by the end of the century." One of the best-sellers of the 18th century was his book 'Primitive Physick, or an Easy and Natural Way of Curing Most Diseases' which ran to 32 editions. Another medical work he published anonymously in 1759, 'The Desideratum: or, Electricity Made Plain and Useful. By a Lover of Mankind, and of Common Sense' was reprinted five times over the next 20 years and expounded all that was currently known about the theoretical and practicalities of medical electricity⁶. By the end of the century, several teaching hospitals in London had installed electrical apparatus. Textbooks recommending treatment protocols were published in London by Tiberius Cavallo⁷ in 1780 and 1786. The surgeon, John Birch became Chief of Medical Electricity at St. Thomas' Hospital, London in 1799 and became a very vocal exponent: "I have had three times seven years tested of the prominent power of electricity and am proud to own that, without this aid, I must have been obliged to perform many more operations"⁸. Lucky the

patients who escaped his knife!

The 18th century witnessed a proliferation of different electrical paraphernalia for treating the whole body in electric air baths, for **drawing sparks** from specific parts of the body or localised discharging of Leydon jars. Conditions treated included hysteria, neuralgias, chronic inflammation and pain, rheumatism, paralysis, menstrual problems. Wealthy patients went to different medical practitioners as they drifted in and out of fashion and charlatans followed in the wake of orthodox medicine. There were notable charlatans: James Graham who, in 1780, installed his "celestial bed" in his "Temple of Health" or "Temple of Hymen" in London to create an 'electric æther' to overcome sterility and impotency; he eventually met his demise and ended up mentally deranged in the Newgate debtors' prison. In the USA, Elisha Perkins, patented electric, metallic tractors which, he promised, produced quick and painless cures for a range of ills when passed over the skin. He was later shown to be a complete fraud.

Unjustifiable and excessive claims contributed to the waning of interest in franklinism both by the lay public and the medical world. However, a new source of interest was on the horizon and there was a resurgence of interest with the development of the electrochemical cell or battery. Unlike the Leydon jar which could produce only one discharge at a time, the battery provided a constant current, albeit at a lower voltage, thereby allowing quantitative studies to be carried out. Static electricity or franklinism produced by mechanical means gave way to direct current or galvanism, produced by chemical means.

Alessandro Volta (1745-1827), Professor of Physics in Pavia extended on some observations originally reported to him by Luigi Galvani working at Bologna University. Galvani was convinced that he had found 'animal electricity' or the vital force which separated life from inanimate objects but Volta realised that a novel type of electricity, as described by Galvani, was not being generated by the frogs under investigation but by a metal strip, made from two different metals, which were part of the experimental arrangement. Volta challenged Galvani's

conclusions and there ensued one of the most famous acrimonious rows in science⁹. Ultimately, Galvani died a broken man although his name has become eponymous for direct current (DC) produced by electrochemical methods. Volta went from strength to strength under the patronage of Napoleon I improving on the bimetal strips, building several different voltaic "piles", "crown of cups" or batteries leading ultimately to the dry cell. Cells weighing several tonnes were produced.

Hans Christian Oësted soon demonstrated that every time a current flows, a magnetic field is produced, thereby discovering electromagnetism - a fundamental for science and technology. The earliest major market for batteries was in telegraph systems in the 1830s. Electricity progressed from being a toy and medical curiosity to a consistent source of energy with the technical potential for industrial processes, for experimenting with the material world and, of course, for medicine. With the waning of franklinism, some medical practitioners were looking for the latest development to give them an edge over the competition.

As with franklinism, general and localised treatments were developed using direct current or galvanism. During the general treatment, the positive electrode was usually applied to the head and the negative to the abdomen or back and a low current applied for the treatment of pain and insomnia. Reversal of the electrodes was indicated for general overindulgence, drowsiness and nervous problems. The strength of the stimulation depended on the number of cells used. La Beaume, in his book published in 1826, recommended daily treatment until the problem started to respond then 3 to 4 times weekly¹⁰. Galvanic baths were developed but the head and cranial nerves were the most common target for local treatment with an array of electrodes developed for headaches, migraines, diseases of the ear, nose and eye, strokes, asthma, diabetes and epilepsy. Treatment to the spine was used for ataxia, paralysis and amenorrhœa; a rectal electrode was used for constipation and a urethral electrode for prostate problems.

In 1821, James Churchill published an extensive treatise on

acupuncture¹¹. His book revised interest in the medicine which had been brought to France from the Far East by missionaries in the 1700s. Researchers in France such as EV Berlioz and JOB Sarlandière^{12,13} extended the traditional writings by publishing their work on electroacupuncture using initially direct current (and later alternating current) to stimulate the needles. Sarlandière produced a model to explain the analgesic effects of electrical stimulation suggesting that the electrical stimulation confused the processes which generated pain, thereby helping to control that pain. Platinum and steel needles were used to stimulate muscles and nerves - even the optic nerve by inserting needles through the eye ball.

The use of gases and volatile organic substances as anæsthetics was developing rapidly in the middle of the 19th century. Although patients could now be unconscious during operations, there were disadvantages attached to these new techniques. Surgeons began to perform longer operations, which increased the severity of wound infections and the other disadvantage was that respiratory depression and cardiac arrest were not uncommon using chloroform. However surgeons developed techniques using batteries to stimulate an arrested heart and restore breathing. Dr Green's paper¹⁴ on the prevention of death by chloroform using galvanism was published in the very first edition of the British Medical Journal. Sufficient cells to generate 300V was not uncommon with electrodes placed on the neck and the lower rib cage on the left side. An arrested heart could also be stimulated by direct stimulation via a needle into the ventricle and by the end of the century, techniques were developed using interrupted or pulsed direct current for closed chest cardiac pacing. However, it was not until the 1950s that cardiac pacing really became established and the first completely implantable pacemaker was used in Sweden in 1958. By 1960, the first independent apparatus which did not require recharging was being used and became the prototype for succeeding generations of pacemakers which have improved the quality of life for millions of patients.

As well as developing techniques to restore heart beat and breathing,

surgeons in the 19th century were putting galvanic currents to surgical use. Heated wires were used for cautery, to remove polyps and tumours and to cause electrolysis in affected tissues (galvanopuncture) to remove warts, moles and malignant tumours for example. Galvanopuncture was used in the treatment of aneurysms to cause blood clots and fibrous tissue to strengthen the damaged artery wall. The union of recalcitrant bone fractures was found to be stimulated by direct current and the techniques devised by Boyer in the first half of the 19th century, pioneered treatments fundamentally similar to those which are used to this day.

The third major invention in the history of the generation of electricity is that of magnetic induction, independently discovered by Michael Faraday (1791-1867) in Britain and Joseph Henry (1797-1878) in the USA around 1831. Both were largely self-educated men. Henry's experimental work in chemistry, electricity and magnetism eventually led him to become the first secretary of the newly organised Smithsonian Institution in 1846. The unit of inductance, the henry, is named in his honour.

Faraday was initially apprenticed to a bookbinder until he was taken under the wing of the famous chemist Humphrey Davy at the age of 21. Faraday is known for his pioneering experiments in electricity and magnetism and is considered by many to be the greatest experimentalist who ever lived. Several ideas that he derived directly from experiments, such as lines of magnetic force, have become fundamental concepts in modern physics. Faraday and Henry discovered that a change in a magnetic field could induce a voltage in a wire or coil. The principles of induction investigated by these two scientists made possible the development of the dynamo or generator and the transformer. The process of generating an electric charge by rotating a wire in a magnetic field inducing a voltage in the wire became known as faradism. Following on from Faraday's early apparatus which was simply a hand cranked wire rotating in a magnetic field, innovation quickly produced induction machines able to produce bigger and bigger shocks. The basic apparatus consists of two coils of

wire - primary and secondary coils. A direct current is passed through the primary coil, a magnetic field is produced with increasing intensity. This changing field induces a current in the secondary coil. Various devices were developed to automatically and repeatedly interrupt the supply to the primary circuit thereby inducing a constant train of electric pulses in the secondary coil. This train was of sine-waves, with polarity, opposite to the primary coil and of unequal amplitude. If this train of electrical pulses was applied to muscles or motor nerves, tetanic contractions were produced giving rise to the term faradic stimulation to describe this phenomenon. Emil Du Bois-Reymond (1818-1897), used the current produced by induction machines (inductoria) to found modern electrophysiology.

Discharges from static and galvanic devices could produce a single twitch in muscle but the new faradic devices could produce a train of electrical pulses and the inductorium was used extensively in physiology laboratories for experimentation, medical diagnosis and treatment. **Guillaume Duchenne**, the French neurologist who first described the most common form of muscular dystrophy in 1868, was an early champion of faradism, an eponym which he first coined. Initially Duchenne used electroacupuncture, studying with Sarlandière and Magendie. Eventually he used moist electrodes on the surface of the skin for treatment. He was a major contributor to our knowledge of human musculature, identifying motor points and range of action of muscles. He reawakened medical interest in galvanic stimulation as well as faradism and his works published in 1872 established electrotherapy as a specific **discipline**¹⁵. With a fuller understanding of electrophysiology, practitioners produced an ever increasing range of **apparatus**, which could apply stimulation to the surface of the skin and to every orifice, sometimes simultaneously and with increasing enthusiasm. Observations on slowing the heart by stimulating the vagus nerve served to heightened expectations even further since faradism could slow down physiological processes as well as speed them up. By 1884, it is estimated that around 10,000 medical practitioners in the USA used electricity as a therapy and the end of the 19th century saw a heyday of electrical medicine.

General faradism was applied to the whole of the body; the patient stood on a copper plate and the other electrode was usually a copper ball covered with a moist sponge which could be moved over the patient's body. Treatment was used for hypochondria, hysteria, dyspepsia, neuralgias, constipation, paralysis, rheumatic pains and insomnia. Total body treatment was often accompanied by local treatment with a variety of electrodes, especially at sites overlying motor points and was used for musculoskeletal problems, neuralgias, infertility, amenorrhœa, constipation, bladder problems, impotency and frigidity, headaches and migraines; the sensory system could be stimulated using electrodes devised for the auditory and nasal canals. Few unpleasant side effects were recorded; Beard & Rockwell, who went on to develop the electric chair in the USA, astutely noted that those of a more nervous disposition received more benefit from treatment than those more phlegmatic¹⁶.

An area of medicine which received the widest interest in the use of electricity throughout the 19th century was pain control, not only pain associated with disease but also that associated with surgery and dentistry. Childbirth had already received the attentions of the electricians - electrical induction of labour had first being carried out in Germany in 1807¹⁷. Electrosleep for use during surgery has been an area of interest in various parts of the world since the 1850s when the first experiments were carried out in Chile. Electrodes are placed on the forehead or mastoid and low intensity, pulsed DC is used¹⁸. However, it is now generally accepted that electrically induced sleep for total anæsthesia is too dangerous for routine use. Electrosleep can be used to relax patients suffering from chronic unremitting anxiety without unpleasant side-effects. The technique of applying low intensity, electrical pulses to the head has accumulated a number of acronyms including CES - Cranial electrotherapy stimulation, TCET - transcranial electrotherapy, NET - neuroelectric therapy. CES appears to be the most widely used acronym. Electrodes are placed on the ear lobes or the mastoid and treatment should leave the patient in a pleasant, alert but relaxed 'alpha' state. A recent review¹⁹ of more than 100 studies on

human participants have demonstrated a number of physiological changes which explain at least some of the beneficial effects of the treatment. These include changes in the electroencephalogram, pulse rate, blood pressure and peripheral temperature. The main indications are insomnia, depression, anxiety but the technique has been successfully used for a range of applications.

Apart from a few enthusiasts, the use of **electrical therapies** gradually declined, a decline aided by the Flexner Report published in the USA in 1910. Early in the 20th century, the Carnegie Foundation for the Advancement of Teaching set up a commission under **Abraham Flexner** to investigate standards in 155 medical colleges. Flexner (1866-1959) was a college director and renowned educator who had previously appraised American education institutions. The Flexner Report produced a rapid revision of medical education in the USA, closing many medical schools and establishing science and experimentation at the core of medical philosophy, following the German, Wissenschaftliches Medicine, model. As secretary of the Rockefeller Foundation's General Education Board, Flexner later channelled \$500 million of private donations into medical education, but amongst the casualties of the Flexner Report were most electrical therapies.

Ever since Aristotle first tried to describe pain as stimulation in excess, many models to explain the perception of pain have been postulated. For almost one hundred years from the mid-1800s, it was believed that sensation was based on four divisions, namely touch, pain, warmth and cold, each with its own type of nerve ending. However this concept of pain was gradually shown to be inadequate as it was realised that different types of pain could be evoked by stimulating different tissues or different layers such as epidermis, dermis, periosteum or muscle. This observation led to the stratification hypothesis of pain. A pattern theory of sensation was then proposed in the 1950s which suggested that groups of nerve fibres in the peripheral nervous system and spinal cord contributed to more than one kind of sensation. These groups excited different groups of nerves within the brain allowing the central nervous system to decode all the input; pain was thought to be produced by

intense stimulation indicated by summation of the input - the higher the input, the greater the pain. This led to the concept that stimulation of particular nerve fibres could evoke different sensations according to circumstances with rapidly conducting fibres inhibiting the transmission of nerve impulses across the nerve junction in a system of fibres which conducted impulses more slowly.

A great surge of interest in electrical pain control followed the electrophysiological investigations by Ronald Melzack and Patrick Wall who, in 1965, published their gate control theory of pain control²⁰. They proposed that selective activation of peripheral, large nerve fibres carrying information to the brain would selectively prevent pain signals being transmitted to the brain. The theory was not based on studies either of pain *per se* or any other type of sensation but was the culmination of several years of electrophysiological studies of the spinal cord in decerebrate and spinal sectioned cats; they incorporated studies going back to the 1920s. The gate control theory gave precision to the concept and added details about the mechanism and location. Around the same time in the USA, Norman Shealy and colleagues had been implanting electrical stimulators within the dorsal spine to help control chronic pain^{21,22,23} and discovered that these devices were equally effective if the stimulation was transmitted via electrodes on the surface of the skin, thereby eliminating the not inconsiderable risk associated with the surgery. Using the gate control theory as the *raison d'être*, Shealy and colleagues then developed equipment which generated low voltage and current stimulation with low pulse repetition rates to activate large peripheral nerves. Stimulation was applied via electrodes stuck to the surface of the skin and was used to control chronic pain²⁴. This treatment became known as transcutaneous electrical nerve stimulation (TENS) or transcutaneous nerve stimulation (TNS). Initially using cumbersome, laboratory style electrical stimulators, Shealy himself acknowledges the first TENS-like device to be the patented ElecTreat which had been manufactured as early as 1918 in the USA and was still available in the 1960s. This battery operated apparatus consisted of a roller, which was an anode, attached to a handle, the cathode. The device was

rolled on the body to treat a range of conditions such as circulation problems, pain and muscle relaxation. Shealy oversaw the design of more compact machines using solid state electronics and producing square or spiked wave forms - waveforms which, in his experience using electroacupuncture, produced the most satisfactory pain control. Following early clinical trials²⁵, it was demonstrated that pain could be relieved in humans by stimulating primary afferent neurons. Long²⁶ was amongst the first to publish reports on the clinical use of TENS machines as we now know them which had been commercially produced since the 1970s with controlled waveform and variable stimulation features .

TNS or TENS was originally developed for the relief of postoperative and chronic pain but is now used to help control pain in a wide range of situations including the acute pain associated with child birth. The treatment requires electrical stimulation to be applied through flexible electrodes which are stuck onto the body in various places depending on the condition being treated. The electrical impulses are administered from a compact 'black box' which can be easily carried around by the patient in their pocket or attached to their belt. The stimulation can be maintained for hours at a time if necessary and the parameters such as the strength of the stimulation and the pulse frequency can be adjusted. Apart from the possibility of minor skin problems there are no known side effects; it is cheap, simple to implement, non invasive, readily accepted by patients, giving them considerable control over their treatment and enhancing the patient/practitioner relationship.

A huge range of TENS equipment has now been produced by medical technicians and practitioners, representing a major growth area in pain control, both clinically and commercially, over the last thirty years. Machines have been variously modified for specific clinical situations, for obstetric use for example and with large knobs for those with difficulty in gripping. Despite the widespread clinical use of TENS, there is little good quality research to justify its popularity. It is something of an indictment of a multi-million dollar industry manufacturing, marketing and prescribing TENS equipment, which is still being used largely on an *ad*

hoc basis some thirty years after its introduction into the armamentarium. Many people have received significant pain relief using TENS machines but their good fortune seems to have been arrived at more by good luck than good judgment.

In this manual we hope to give practitioners clear guidelines for treatments using TENS without overloading with technical information so that their patients can benefit from a systematic approach to the design of treatment regimes.

2. TENS: some possible mechanisms

2.1 Placebo

2.2 Gate control theory and neurological explanations

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2.1 Placebo

Critical reviews of controlled medical trials have suggested that the placebo response to a wide range of treatments in various guises is about 30-35% for chronic pain. This proportion has been long established as typical for many medical procedures and chronic pain¹. Beecher reported also that for acute pain induced in the laboratory, the placebo effect could be as low as 6%.

It seems that procedures involving TENS produce typical placebo responses. Benefits from TENS have long been attributed to placebo effect or autosuggestion^{2,3}. Short term success rates of 25-30% are typical of placebo response and longer term positive responses to TENS treatment has been attributed to spontaneous recovery⁴. Thorsteinsson *et al.*⁵ found the placebo analgesic effects of TENS to be approximately 32%, typical of double blind analgesia studies using medication. It has also been suggested that the main positive impact of TENS is that it enables increased activity rather than controlling pain control per se with subsequent positive reactions from patients^{6,7}. On the other hand, Long & Hagfors⁸ reported that for postoperative pain, results were better than would be achieved by long term placebo response. However, from all the experimental and clinical evidence, it seems that a complex model, involving more than one mechanism, is often required to describe how TENS works. From the practitioner's point of view, the argument about placebo effect can become sterile; our main concern is getting patients better and to dismiss positive outcomes using unorthodox approaches to medicine (as TENS was once considered) as placebo and not acknowledge that placebo plays a significant part in any form of medicine, is intellectually corrupt.

2.2 Gate control theory and neurological explanations

2.2.1 Introduction

2.2.2 For the theory

2.2.3 Contra the theory

2.2 Gate control theory and neurological explanations

2.2.1 Introduction

Pain is not a simple sensory experience but has closely woven physical and emotional strands within its context. A working definition is “an unpleasant sensory and emotional experience associated with actual or potential tissue **damage**”⁹ which occurs primarily as a result of a noxious stimulus activating myelinated and nonmyelinated nociceptors and ultimately depends on interpretive processes in the neurons of the cerebral cortex. Perception of pain is very individual and, although pain thresholds tend to be constant, tolerance of pain varies considerable between individuals. Since the time of Aristotle, who explained pain as an emotion, stimulation in excess, an opposite to pleasure, several models to explain the perception of pain have been postulated. For almost one hundred years from the middle of the 1800s it was believed that sensation was based on the four divisions touch, pain, warmth and cold each perceived by its own type of nerve ending. However, this specificity theory of pain was gradually shown to be inadequate as slowly it became realised that different types of pain could be evoked by stimulating different tissues or different layers such as the epidermis, dermis, periosteum or muscle, the so called stratification hypothesis. This hypothesis was gradually superseded by the pattern theory of sensation. It was proposed in the 1950s that groups of nerve fibres in the peripheral nervous system and spinal cord contributed to more than one kind of sensation, producing a stimulation pattern which is then interpreted by the brain. These fibre groups excited different neuron groups within the brain, allowing the central nervous system to decode all the input; pain was thought to be produced by intense stimulation produced by summation of the input. This led to the concept that stimulation of particular nerve fibres could evoke different sensations according to circumstances; rapidly conducting fibres could inhibit the transmission of nerve impulses across the synapses in a system of fibres which conducted impulses more slowly.

The gate control theory of pain was published in 1965 by Ronald Melzack and **Patrick Wall**¹⁰ as a culmination of several years of in vitro and in vivo studies on the electrophysiology of the spinal cord in decerebrate, spinal

sectioned cats. The theory incorporated studies going back to the 1920s when the idea that activity in large nerve fibres could inhibit activity in more slowly conducting fibres, in some parts of the nervous system at least, was first proposed. The theory put forward by Melzack and Wall gave precision to this concept adding detail about the possible mechanism and location. The theory was not based on studies of the perception of either pain per se or any other type of sensation.

2.2.2 For the theory

Melzack and Wall's theory of pain control proposed that within the substantia gelatinosa in the dorsal horn of the spinal cord, a presynaptic **gate control mechanism** monitors input from the peripheral nervous system before it passes to transmission or T cells from where neural mechanisms for perception and response are activated in the higher centres. The gate, effectively a portal to the central nervous system, is held slightly ajar by the continuous input reaching the spinal cord from the periphery via mainly small myelinated and non-myelinated fibres (A δ and C) which maintain a state of hyperpolarization thereby facilitating transmission of nerve impulses. These fibres adapt only slowly to changes in input.

Large (A- β) fibres are inactive until the status quo is disturbed but stimulation at the periphery produces a proportionally greater increase in the firing rate of the large fibres compared to the smaller fibres. The impulses from the large fibres start the T cells firing but at the same time start to close the presynaptic gate thereby decreasing the amount of information reaching the T cells and hence higher centres. As the stimulation intensity increases, input from the small and large fibres tend to cancel each other out. However, **during prolonged stimulation**, the large fibres adapt to the stimulus, the proportion of the input coming via the small fibres thereby increasingly forces open the gate, output from the T cells rises rapidly and the stimulus is relayed to the higher centres. The gate control theory proposes that pain is perceived and suitable responses evoked when the output from the T cells reaches a critical level. Thus the effects of stimulation at the periphery will depend on the total number of nerves firing, the specialised function of those nerves, the frequency of impulses and the relative activity in the small and large fibres.

Melzack and Wall argued that if the activity in the large fibres could be kept high, then the gate is kept relatively closed, T cell output will not increase and responses to pain will not be evoked. This concept has led to the development of various therapies which try to control chronic pain by selectively increasing the activity in large fibres in the indicated

dermatome(s) using electrical excitation thereby maintaining the gate in a relatively closed condition. Transcutaneous electrical nerve stimulation (TNS or TENS) is one such therapy which was originally developed for the relief of postoperative and chronic pain. Other counter irritations such as rubbing, hot and cold treatment or massaging specific areas also play their part in closing the gate or portal.

The gate control theory M_{ck} was published by Melzack¹¹ and Melzack and Wall¹² to include developments in pain research which had taken place since 1965 in particular Melzack and Loeser's work¹³ on phantom limb pain in paraplegics. This lead them to conclude that pain did not originate in the sympathetic system but was produced by a central pattern generating mechanism. The modifications included an excitatory function for the substantia gelatinosa as well as inhibitory, pre- and/or post synaptic inhibition, and active inhibition descending from the brain stem to the dorsal horn, influenced by sensory input after the gating mechanism.

Two reasons have been given to explain how such a therapy can instigate long term pain control¹⁴:

1. by controlling pain and thereby restoring mobility to a joint, the input from large fibres increases proportionally more than from small fibres thereby closing the gate,
2. it has been suggested that, within the central nervous system, pain can be learnt and that an intense, local stimulation can somehow eradicate the memory of the pain.

Melzack¹⁴ and Livingstone¹⁵ both have proposed that protracted pathological pain may produce chains of self-exciting neurons which act like a pain memory. Intense sensory stimulation would disrupt this abnormal activity within the nervous system giving pain relief beyond the duration of the stimulation. However, although TENS is now well established as a clinical procedure in a wide range of settings, the neural mechanisms are still not well understood, although spontaneous and noxiously evoked activity in the dorsal horn neurons can be modified using commercially available TENS machines¹⁶.

2.2.3 Contra the theory

The gate control model has had a major impact on the treatment of pain and often gets quoted almost like a mantra when explanations are sought to explain how TENS may produce pain control. But as a theory it is not tenable in all respects and it does not seem generally realised that the theory has been expansively criticised. Nathan¹⁷ in his comprehensive review, analysed the theory under a number of different headings:

- which parts of the theory were based on accepted facts and which parts were conjecture,
- which facts are acceptable to both the protagonists and opponents of the theory,
- which facts were accepted by advocates of the theory but denied by its opponents,
- the interpretation of those accepted or unaccepted facts,
- which pertinent information has been omitted from the theory.

For a full account of Nathan's arguments the reader is advised to consult his original paper. Amongst other arguments, he points out that:

- a. the proposed properties and function of the T cells is hypothetical, although cells have been found in lamina V of the spinal cord which might exhibit the necessary characteristics;
- b. although inhibition at the posterior root terminals is generally accepted, histological evidence for its existence has not always been found;
- c. the case for hyperpolarisation at the presynaptic site has not been made;
- d. the known specificity of the stimulus or peripheral somatic nerve fibres and the stratification hypothesis have been omitted from the theory;
- e. there is no simple antagonistic relationship between large myelinated fibres and small myelinated and nonmyelinated fibres and, from his own experiments to test this relationship, he concludes that the theory is wrong;
- f. for various pathological states, it should be possible to predict using the theory whether or not a patient will be in constant pain or even perceive any pain at all. Selective removal of large fibres

should result in all stimuli causing pain and the selective removal of small fibres should result in no stimuli producing any pain. Some conditions, such as herpetic neuralgia do seem to fit this prediction. However, other pathologies, such as various neuropathies with selective destruction of large fibres which do not result in every stimulus producing pain and others showing that a decrease in small fibres do not render the patient immune to pain, as would be predicted by the theory. Nathan points out that any pathological condition which does not produce a syndrome which could be predicted using the theory, renders it untenable.

Ultimately, Nathan concludes that the concept that large fibres do inhibit activity in more slowly conducting fibres is one of several mechanisms controlling pain within the central nervous system and that the site and mechanism as proposed in the gate control theory are wrong. He goes on to say that "...Ideas have to be fruitful; they do not have to be right..." and concedes the theory to be a useful concept. He also warns against drawing too profound conclusions from neurophysiological experiments where observations are made on single nerves or bundles of nerves which are "anatomical entities" and "not the physiological entities of normal life" because "the only normal entrance to the nervous system is via its receptors".

There are several clinical observations on the control of pain which are not in accord with the gate control theory. TENS was developed on the strength of the theory for the control of chronic and postoperative pain using low intensity, peripheral electrical stimulation applied locally within the same dermatome as the pain. However, pain can be controlled by stimulation distant to the pain. It has been suggested that this stimulus has to be intense and this observation has given rise to the concept of diffuse noxious inhibitory control¹⁸. It has already been mentioned that such intense stimuli could erase a "pain memory"¹⁴ but it has been demonstrated that a distant stimulus at or above the pain threshold will inhibit the convergent neurons which receive a variety of inputs thereby suppressing pain elsewhere. These neurons are situated in lamina V of the spinal cord and the trigeminal complex. The inhibition remains after the

noxious stimulus has been removed but only for a few minutes and leaves much to be desired as a clinical procedure.

Treatment need not be carried out in the same dermatome as the pain as would be required by the gate control theory. Any stimulus applied to acupuncture points, for example, does not have to be a noxious one to obtain a satisfactory result; if electrical stimulation is carried out, the parameters of the stimulus such as wave form and frequency are more important than intensity. Electromagnetic fields and 'cold' lasers generating 2mW of power have been used for the control of pain using a stimulus which is both non thermal in that there is no perception of increased temperature by the subject although there is a physiological temperature rise of less than 0.1°C) and also non tactile - the patient need not be in physical contact with the apparatus. In vitro studies using electromagnetic fields at low frequencies and low intensities have shown that physiological and behavioural responses can be evoked using stimuli which induce currents within biological systems which are some eight orders of magnitude below that required to stimulate nerves to fire.

Putting to one side the subjective aspects of the perception of the stimulus known as a 'pain', the stimulation of nerves is obviously a prerequisite for the perception of pain. However the mechanisms explaining pain control are complex and multiplex and the neurological models which have been proposed to help explain the control of pain are inadequate in explaining many of the clinical observations involving pain control. There is sufficient evidence both clinical and academic to provoke discussion on biochemical and biophysical aspects of pain control. With an open mind, it should be possible to abandon dogma and produce a synthesis.

2.3 Biochemistry

2.3.1 Opioid peptides

2.3.2 Monoamines

2.3.4 Stimulation frequency

2.3.4 Psycho-immuno-endocrine network

2.3 Biochemistry

2.3.1 Opioid peptides

Perhaps the best known group of compounds which have been associated with pain control using electrostimulation are the opioid peptides. In 1975 Hughes¹⁹ identified two peptides in brain tissue with properties like morphine. These two enkephalins were also found in the substantia gelatinosa and periventricular grey matter. A group of compounds which includes the endorphins and enkephalins have now been found which are a subset of a much larger group of regulatory peptides and have properties similar to morphine including analgesia. The discovery of the opiate receptor binding for one group of endogenous opioid peptides, the enkephalins, in the central nervous system led to the anticipation of a specific rôle for these peptides in pain control. Endogenous opioid peptides have been implicated in pain since the administration of endorphin and enkephalin into the central grey area of the brain stem or brain ventricles was shown to produce analgesia. However, subsequent work on the distribution of the receptor sites for opioids, and the proliferation in the number of opioid peptides, not all of them with analgesic properties, has increased the range of functions in which they seem to be involved.

The 18 or so opioid peptides which have been described to date are derived from three polypeptide precursors²⁰ and can be divided into two, possibly three, groups, namely:

- the endorphins
- the enkephalins
- and the dynorphins.

The endorphins are fragments of the pituitary peptide, β -lipotropin, sharing a common precursor (pro-opiocortin) with ACTH and other hormones. In man, the endorphin receptors are distributed in the limbic system. The receptors for the enkephalins have a more spinal distribution in laminæ I and V. Both groups seem to be ideally sited for pain control; in laminæ I and V noxious input is thought to be processed and the endorphin receptors are located in structures thought to be involved in pain modulation. However, opioid peptides are widely distributed throughout

the body but in generalising, spinal sites use dynorphins and enkephalins to block transmission of pain signals, the midbrain uses enkephalin and the pituitary releases β -endorphin into the blood supply and cerebrospinal fluid.

Many of the biochemical changes occurring during pain control procedures have been investigated using analgesia produced by electrical stimulation, either via chronically implanted electrodes in the brain or the stimulation of acupuncture points using needles or surface electrodes. In fact, the "endorphin effect" has been grasped by many as being the mechanism to explain the control of pain treatments using the acupuncture system. Many of the biochemical changes elucidated using electroacupuncture have been presumed also to take place using TENS; it is considered that it is the input of the electrical stimulus with particular characteristics which is the important part of the therapy and not the means of conveying the electrical input *per se*.

The number of papers identifying opioid peptides in analgesia produced by acupuncture and electroacupuncture has mushroomed since the early studies in the 1970s^{21,22,23,24,25}. These early studies were followed by a large number of publications mainly confirming the involvement of endorphins in electroacupuncture analgesia by making systematic use of endorphin antagonists.

There are two basic ways of demonstrating the part played by endogenous opioid proteins in pain control; to monitor changes in concentration within the body (eg. within cerebrospinal fluid) or to monitor the effects of agents known to be antagonists to opioid proteins such as naloxone, a powerful and rapidly acting antagonist to opiates²⁶. Initially two groups were working with these antagonists. Pomeranz and Chui²¹ used electrical stimulation at an acupuncture point in mice to demonstrate the effect of naloxone. Meyer *et al.*²² controlled experimentally induced toothache using needling at a specific point and, using a double blind design, showed that naloxone inhibited the control of pain in the affected teeth. A dose response curve to naloxone was produced by Cheng &

Pomeranz²⁴. However, studies on the use of endorphin antagonists have been criticised for drawing too profound conclusions because of the potential side effects of the antagonists and the possible nonspecific or too specific nature of the antagonism^{27,28,29}. Published data involving the use of naloxone is contradictory as is emphasised in a short review³⁰, but there is now evidence from 15 other different experimental approaches to these investigations providing support for the involvement of endorphins.

For example, in treatments involving electrical stimulation:

- endorphin levels in cerebrospinal fluid have been shown to increase in the treatment of subjects in chronic pain with low waveform electroacupuncture accompanying a decrease in reported pain³¹. All subjects reported pain relief within 20min after stimulation. This was accompanied by a significant increase in the concentration of β -endorphin in the cerebrospinal fluid. Plasma levels of met-enkephalin and β -lipotropin, the pituitary fragment of which β -endorphin is itself a fragment, as well as endorphin levels themselves, have been shown to increase during analgesia produced by TENS³³. Patients' response to TENS has been demonstrated not to be related to baseline plasma opioid levels³⁴.
- four different types of antagonist to opiates have been demonstrated to block analgesia produced by acupuncture^{24,35};
- the rôle of pituitary β -endorphin is not clear although plasma levels of met-enkephalin and lipotropin, the pituitary protein of which β -endorphin is a fragment, as well as β -endorphin levels themselves, have all been shown to increase³²;
- release of ACTH has been shown to accompany the release of pituitary endorphin during acupuncture analgesia^{36,37,38} which stimulates cortisol release from the adrenals and explain how electroacupuncture can help control inflammation;
- it has been demonstrated also that cortisol analogues not only inhibit the release of endogenous cortisol but also the pro-opiocortin-related peptides such as ACTH, β -lipotropin and β -endorphin³⁹. Practitioners have reported relatively poor results with patients who have received treatments involving cortisone's up to six months prior to acupuncture treatment. A possible explanation could be that

cortisol analogues not only inhibit the release of endogenous cortisol but also the pro-opiocortin-related peptides such as ACTH, β -lipotropin and β -endorphin, whilst met-enkephalin concentrations remain unchanged, suggesting a rôle of pituitary opioid peptides but the model is currently far from clear

- other evidence for the involvement of opioid peptides and other regulatory peptides in analgesia also comes from more recent studies using antibodies to these **peptides**^{40,41,42}. Antibodies to β -endorphin injected into the periaqueductal grey area of the brain decreased the analgesic effect of electroacupuncture in rabbits and antibodies to met-enkephalin injected into the spinal cord were similarly **effective**⁴⁰. Antibodies to the non opioid regulatory peptide, substance P, when administered intrathecally potentiated analgesia but decreased analgesia when injected into the periaqueductal grey area; it has been suggested that substance P is released by sensory fibres carrying information about painful stimuli to the higher centres. However, there are questions about the specificity of the antibody reaction which have not been fully answered.

There has been considerable research into the biochemical rationale behind the use of electroacupuncture and other electrical therapies for the treatment of withdrawal symptoms associated with a range of licit and illicit drugs. It is unlikely, one mechanism alone explains the effects of electrostimulation on the control of withdrawal from a range of addictive drugs such as heroin, benzodiazepines, alcohol and nicotine, except perhaps Ca^{++} ion concentration changes. To take heroin as an example, there is considerable laboratory and clinical evidence that electrical stimulation can alleviate heroin withdrawal symptoms:

- transcutaneous cranial electrical stimulation has been shown to attenuate withdrawal from opiates in rats as well as potentiate morphine **analgesia**⁴³;
- Ng and **colleagues**⁴⁴ at the National Institute of Health in the USA working on rats addicted to morphine have demonstrated significant alleviation of withdrawal symptoms when administered naloxone after electrical stimulation to the ear concha;
- electroacupuncture and auricular electrical stimulation of addicted

mice has been shown to decrease withdrawal symptoms^{45,46};

- to determine whether or not endogenous opioid peptides are implicated in the use of electrostimulation in the successful treatment of heroin withdrawal symptoms, plasma and CSF levels of immunoreactive β -endorphin and met-enkephalin have been investigated in withdrawing subjects⁴⁷. During withdrawal it was found that the concentration of β -endorphin in plasma and CSF were markedly elevated but subsequently unchanged by auricular acupuncture alone. Mean basal CSF levels of met-enkephalin were lower than in unaddicted subjects. After electrostimulation, CSF met-enkephalin increased significantly with an associated relief from symptoms.

2.3.2 Monoamines

Compared to the work on endorphins and related peptides, there is less extensive evidence that monoamines, especially 5- hydroxytryptamine (5-HT or serotonin) and noradrenalin (norepinephrine), are implicated in acupuncture analgesia:

- antagonists to 5-HT block acupuncture analgesia and increased synthesis and metabolism of 5-HT has been recorded during stimulation^{48,49,50,51,52,53};
- numerous experiments have demonstrated that lesions in the raphe magnus, the area in the brain stem containing most of the 5-HT supply, impairs or blocks analgesia^{49,54,55};
- in a double-blind study, acupuncture analgesia was potentiated in patients using clomipramine which blocks the uptake of 5-HT⁵⁶;
- less work has been carried out into the effects of noradrenalin in analgesia produced during acupuncture but it has been shown that injections of noradrenalin antagonists into the theca does block analgesia⁵⁷.

Thus it can be seen that there is a considerable amount of work, a summary of which has been presented here, indicating the biochemical changes which do take place during various forms of therapy involving electrostimulation and their involvement in pain control.

2.3.3 Stimulation frequency

A complicating factor of considerable interest is the evidence that the characteristics of the analgesia produced can be dependent on the frequency of the pulse making up the electrical stimulus⁵⁸. Electrical stimulation at around 2pps produces a more generalised and enduring analgesia compared to stimulation at 10-100pps. Stimulation at higher frequencies is partially or totally inhibited by 5-HT antagonists and that at low frequencies by opioid peptide antagonists indicating the involvement of two separate biochemical mechanisms^{49,53,54,59,60}. Analgesia produced at low frequencies less than 10-15pps is inhibited by naloxone suggesting opioid peptides predominate the mechanism; analgesia produced using stimulation around 200pps is at least partially if not totally inhibited by p-chlorophenylalanine, an antagonist to the monoamine 5-HT and at these higher frequencies, it seems that a mechanism involving 5-HT predominates. Analgesia produced using TENS with high stimulation frequency has been demonstrated to be unaffected by the opiate antagonist naloxone, whereas analgesia produced by low frequency TENS is at least partially reversed by naloxone, again indicating two mechanisms based on opiates and non opiates systems^{61,62}. O'Brien *et al.*⁶³ showed TENS to have no effect on β -endorphin concentration in plasma. unlike Hughes *et al.*⁶⁴ who demonstrated increased plasma levels using both high and low frequency TENS stimulation. Experimentally TENS at different frequencies has been shown to produce a range of analgesic responses to pain threshold using iced water; Ashton *et al.*⁶⁵ showed 8pps to be effective but 100pps to ineffective whereas Johnson *et al.*⁶⁶ showed the effective frequency range to be between 20-80pps only.

The frequency dependent nature of the possible biochemical mechanism explaining the analgesic effect of various electrical therapies is in state of some confusion compounded by a range of observations suggesting that such variables as circadian rhythms, menstruation and other medication may effect the response to TENS treatment⁶⁷.

It is important to emphasise the frequency-dependent effects which have

been demonstrated with various electrical treatments but mainly electroacupuncture and also using chronically implanted electrodes in the brain, because it implies that the body is able to distinguish between and use discrete packages of information.

2.3.4 Psycho-immuno-endocrine network

It is also important to emphasise the erosion of the strict divisions between the nervous, endocrine and immune systems over the last few years with the unravelling of a massive system of some fifty or more regulatory peptides (including the opioid peptides) acting as hormones, local regulators and neurotransmitters. The full complexities of this system are gradually emerging; nerve cells may contain more than one signal propagator, releasing a mixture of regulatory peptides and monoamines such as 5-HT and dopamine, in a potentially very large number of combinations. The discovery of receptor sites for the benzodiazepine group of drugs on the monocyte white blood cells⁶⁸ as well as increasing indications that opioid peptides and other regulatory peptides are also involved in immune reactions, as well as influencing mood, has added a whole new dimension to the classical concepts of discrete and separate nervous, endocrine and immune systems⁶⁹.

All three systems have been bundled up as the 'psycho-immuno-endocrine network' and it is being suggested that this network could regulate the whole of the body intimately uniting mood, mental state, susceptibility to illness and the so-called 'psychosomatic' aspects with the organic aspect of being ill. This pharmacological network links major events in peoples' lives such as divorce and bereavement with their increased susceptibility to becoming ill as well as more trivial illustrations such as the increased incidence of cold sores accompanying feelings of unhappiness. Treatment of the acupuncture system has been shown to produce neurohormonal and immunological changes^{70,71,72,73,74,75,76,77,78}. High intensity electroacupuncture in horses increase cortisol levels⁷². Electroacupuncture elevates blood cortisol levels in naive horses; sham treatment has no effect. These more recent developments offer the possibility of more profound biochemical explanations of the mechanisms of treatments involving electrical stimulation, more profound than the simple coupling of the "endorphin-effect" and pain control.

2.4 The body electric

2.4.1 Introduction

2.4.2 Metallic conduction

2.4.3 Ionic conduction

2.4.4 Semiconduction

2.4.5 Other sources

2.4.6 The model

2.4 The body electric

2.4.1 Introduction

Slowly but surely, the electrochemical aspects of living systems are being considered in the context of health and illness; electricity is very prevalent to all life, playing an integral part in metabolism, differentiation, morphogenesis and coordinating the systems described as 'life'.

There are three methods of conducting electricity:

- metallic conduction
- ionic conduction
- semiconduction.

2.4.2 Metallic conduction

Metallic conduction which can be imagined as multitudes of electrons moving along wire or metal. Conduction is fast and can be carried over long distances. Metallic conduction is not known in any form of life. The two other methods have direct involvement in biological systems.





2.4.3 Ionic conduction

Ionic conduction is produced in solution by the movement of ions and is very prevalent in biological systems; a familiar ionic conduction current is the conduction of nerve impulses. Ionic currents work well over short distances such as the membrane surrounding nerve fibres or cells but soon expire over greater distances.

Electrical responses involving ionic currents in biological tissue have been used therapeutically; for example Björn Nordenström has shown that tumours have a negative polarity compared to surrounding tissue which can be reduced by the application of a positive charge. His remarkable pioneering work in this area involving biological electrical currents and circuits, has led to innovative treatments for some **cancers**⁷⁹.

Nordenström proposed a model of closed biologically electric circuits to explain at least aspects of responses to needles and electrostimulation therapies. In the 1950s, he started to investigate series' of patterns he had noticed on x-rays of lung tumours and other carcinomas. His observations led to a long series of experiments and the discovery of a circulatory system based on electric potentials which generate spontaneously in tissues. Various metabolic processes ensure that electric potentials occur in normal organs as well as in damaged or diseased organs. Nordenström has shown that these potentials actually drive electric currents along what he has called biologically closed electric circuits (BCEC) which are an additional circulatory system for selectively transporting charged molecules between the blood stream and various tissues. The 'wiring' of the circuits is made up of the electrically insulated blood vessels and interstitial spaces which can carry these ionic currents over both long and short distances. Conduction through the plasma is produced by water, electrolytes and complex molecules which carry charge along an electrical potential gradient. Potential differences are set up during normal metabolism to drive the system. Injury enhances electrical activity in the system, injury currents would be an example, to enhance healing processes.

Transport along these circuits leads to modification of tissues with implications for healing and the development of artificial induction of currents in the circuit for therapeutic purposes. The system can involve nonionic compounds such as glucose and oxygen which conserve their electrical energy until the metabolic conditions are suitable for its release, as well as the electric energy carried by ions which is always readily available.

Physiological responses which Nordenström has described using this model includes the production of scar tissue, calcification in damaged tissue, bone repair, carcinogenesis, the accumulation of white blood cells at the sites of tissue damage and the production of thromboses. Degrading tissue produces an electropositive field attracting leukocytes and platelets. He suggests that a similar mechanism is set up by lung lesions producing emphysema.



2.4.4 Semiconduction



Semiconduction is the third method of electrical conduction. Semiconductors have characteristics of both insulators and conductors depending on temperature. Semiconduction (or solid state physics ie. involving no moving parts or gases) has been the essential cornerstone in the development of all aspects of electronics over the last fifty years and has been investigated within biological systems since the 1940s. The application of solid state electronics to biological systems and medicine can explain many events which cannot be accounted for within the more orthodox framework of biochemistry bound by lipid/protein membranes and may have a rôle to play in illness, pain and pain control.

Semiconduction requires materials to have a very orderly structure so that electrons can move from one atom nucleus to another. Crystals and proteins, for example, have the necessary structure. At normal temperatures some electrons break their bonds and are available to 'flow' in an applied electrical field. Holes in the crystalline structure also give rise to free electrons as do impurities or other defects in the structure. If an 'alien' atom takes up station within the lattice, a process known as doping, this can dramatically change the local electrical environment and clouds of electrons would be free to move around the lattice causing a negative current to flow. The impurity may have too few electrons, in which case other electrons will flow to fill the deficit causing a positive current. Semiconductors are inefficient in that they can carry only small currents but this current can be readily carried over long distances.

Albert Szent-Görgyi von Nagyrapolt, a biochemist and physician who won the Nobel Prize for Medicine in 1937 for his work on vitamin C and biological oxidation and the catalysis of fumaric acid, first introduced the concept of semiconduction into the biological arena during the 1940s. He postulated that many biological molecules could support semiconduction. For example, the structure of proteins is organised such that it can function as a crystalline lattice, a prerequisite for a semiconductor. The lattice allows movement of electrons around the macromolecules, not just around the atoms making up the molecule, and thus have the potential to

be carriers of information around cells, tissues and the whole organism. He expanded his **ideas**⁸⁰ to conject that electrons could flow over long distances along chains of macromolecules within biological systems and without losing energy - "Single molecules are not necessarily sharply isolated and closed units. There is more promiscuity among them than is generally **believed**"⁸¹. The conserved energy could be used as an analogue information system for growth, self repair and perhaps other fundamental biological processes. He was the first to suggest application of electromagnetic fields to repair bone. The system Szent-Györgyi proposed would be separate from, but possibly associated with the nervous system or glial system.

2.4.5 Other sources

Other potential sources of electricity within the body are piezoelectricity, pyroelectricity and photoelectricity.

Piezoelectricity is produced by some materials when under mechanical stress or pressure. Positive and negative charges are produced on opposing faces of the substance. A now rather dated example with which you may now be less familiar since the advent of the CD player, is the stylus of a record player. The distortions of the sapphire or diamond stylus produced by the grooves in the record generate a signal which is amplified to become your best-loved tune. Piezoelectricity in biological materials was first observed in wool and hair⁸² and others since shown to exhibit this effect include tendon, bone, dentin, silk, aorta, intestine, most biological macromolecules such as nucleic acids, proteins and polysaccharides in solid and liquid states, wood and trachea..

Piezoelectric phenomena in bone has received most attention after the pioneering work of Fukada and Yasuda⁸³. The physiological rôle of piezoelectricity has yet to be fully evaluated; in bone the effect may be the underlying mechanism in the adaption of bone 'architecture' to best fit specific functions (the controlling factor behind the surgeon J. Wolff's observations in the 1890s that stresses on bone affected its morphology) or regulate bone growth and repair⁸⁴. Maintaining movement to produce stresses in bone is essential for bone physiology and work with astronauts, who have spent a long time in space, has shown that gravity is also important. The periosteum is stimulated at sites of compression stress causing bone to grow and the piezoelectric component within the bone appears to be the collagen⁸⁵.

Pyroelectricity results as an electric charge on opposite faces when a crystal is heated and the effect can also be manifest in organic materials such as bone and tendon⁸⁶. Dielectric properties of bone may also be important in growth^{87,88}.

Photoelectricity is produced by the transfer of energy from light illuminating

a substance to electrons within the substance.

Models have been proposed incorporating these electronic phenomena in a range of biological process including homœostasis⁸⁹, phosphorylation during photosynthesis⁹⁰, enzyme activity⁹¹, nerve conduction⁹² and a range of responses to injury and healing processes. As well as internal electrical fields playing an important part in cell differentiation and growth, cell migration and morphogenesis, many different cell types have been shown to be sensitive to externally applied fields at physiological strength. During differentiation electrical conductance at the site of limb buds increases⁹³. These small groups of cells which dictate the development and future of a much larger groups of cells are called organising centres and typically they exhibit a high density of gap junctions and a potential difference of up to 100mV is maintained across the epithelium^{94,95}. Parallels have been drawn between these biologically very active organising centres for morphogenesis and growth and electrically active acupuncture points on the surface of the skin⁹⁶.

2.4.6 The model

As well as the biologically closed electrical circuits proposed by Nordenström, there are a number of other possibilities for the transmission of all this information in cells, tissues and organs and ultimately the whole individual using semiconduction. As we have already noted, Szent-Györgyi pioneered the investigations into the potential of **macromolecules**⁸⁰. The cytoskeletal has possibilities for supporting long range coordination and information **processing**⁹⁷. An information and control system using direct current (DC), analogue electrical signals, which runs in concert with but separate from the nervous system, has been postulated to explain how acupuncture might **work**^{98,99} and can be extended to include a range of electrical therapies. These signals are carried via the neuroglia to an integrating centre with output to the sites of response.

Acupuncture points are considered to be analogous to booster stations or amplifiers along the channel which are likened to transmission lines for the DC signals. **Becker**⁹⁸ describes the acupuncture system as running alongside the nervous system as an analogue information network; DC currents are flowing outside the neurons and do not appear to be produced by the neurons themselves. It seems to be a rudimentary information system running alongside and integrating the more 'advanced' system based on neurons. In the model he proposes, stimulation at the points, such as the insertion of metal needles, would cause "a propagated perturbation" within the information system acting directly on a perineural system or the nervous system via the perineural system. Small perturbations around singular points can have decisive effects on a system. It has been postulated that, if the glial system is stimulated during treatment, then repair processes may be initiated or accelerated; the system is an integrating information network with distinctive direct current electrical and semiconduction characteristics which may be made of macromolecules within connective tissue or be associated with but separate from the nervous system.

Acupuncture points and channels do exhibit specific electrical properties

and changes in these characteristics can be used for diagnosis and prognosis.

Certainly within the central nervous system, a steady DC potential exists running longitudinally from the front of the brain. The olfactory lobes are negative with respect to the occipital area¹⁰⁰. This potential is thought to have a functional rôle in brain activity and may be related to consciousness because manipulation of the DC potential by applying appropriate DC currents can induce anæsthesia or have a tranquillising effect¹⁰¹ although it has been reported that general anæsthesia weakens the DC field¹⁰². This DC system appears to be associated with the glial system which makes up 90% of brain tissue. At the surface of the body, a DC field can be detected which has an obvious relationship with the underlying central nervous system. Positive areas are found over the brain and the brachial/lumbar aggregations of nerve tissue; the periphery is negative with respect to this positive central core¹⁰³. It has been shown that stimuli from outside the body can produce changes in the DC electrical components within the central nervous system. It is recognised that emotion plays a part in illness, pain tolerance and healing. This integration can take place through the DC system and could help explain the importance of the patient/practitioner relationship in restoring or maintaining health and the possible therapeutic outcomes using healers and Shamans.

The DC system under discussion seems to be present in all forms of life, from the most primitive to the most advanced, regulating both growth and regeneration, transmitting and receiving signals associated with injury. These signals have been shown to be important in the regeneration of tissue. The electrical potential of cells is affected by damage due to trauma. At first, after injury, the damaged area exhibits a higher electrical resistance compared to adjacent tissue. This decreases electrical flow through the injured site because the flow will take the path of least resistance around the injury, decreasing cellular capacitance, impairing healing¹⁰⁴. Injury is usually accompanied by pain which is registered by the central nervous system. However, stimulation of the DC system (or the damaged area directly) could regulate activity at the area of trauma, initiating and

maintaining healing. It does seem that intact nervous tissue must be functioning within the vicinity of the area under repair. The DC information system which may be open to manipulation by various means including electrical stimulation, application of light or the induction of electrical currents using magnetic fields⁹⁸.

This model is proving very valuable in describing essential functions for life which cannot be explained in the framework of biochemistry and biological membranes. Robert Becker first suggested that the DC system under consideration has solid state, semiconductor characteristics^{98,99}. Measuring conductance using multiple fixed electrodes at 28 acupuncture points and a direct current electrical source, Motoyama describe two characteristic responses, one measured in μ sec and the other tens of seconds¹⁰⁵. He also concludes that the fast response was due the semiconductor characteristics of the system being measured.

Semiconductor effects may be important in pains with no apparent cause. Fields of disturbance are created by a build up of electrical charge. These fields may be discharged directly by shorting the electrical charge without correcting the underlying cause, leading to a reoccurrence of the problem. Normal conductivity can be restored using various treatments including biphasic electrical stimulation, lasers, electromagnetic field therapies or light. The mechanism can be explained by a semiconductor gating mechanism which involves a DC data transmission system separate from, but in close association with, the nervous system.

Living systems demonstrate homœostasis over a wide range of external influences but tend to logarithmic responses to external stimuli. This implies the presence of high gain amplifiers and diodes in a feedback loop would produce such a logarithmic response; in electronics precise negative feedback control relies on high gain amplifiers. Because we are dealing with a DC electrical system, a number of conventional electrical circuits can be applied to explain the observed phenomena such as electrically active acupuncture points acting as diodes which would explain changes in electrical activity at points due to a current of injury, for example, produced by a trauma¹⁰⁶. When considering the treatment at these points,

the possibilities must be extended beyond the commonly recognised needling to include acupressure, lasers with or without tactile stimulation, electromagnetic field therapies which induces currents in biological tissues and any form of electrical stimulation with or without needles including TENS. Since biological tissues can exhibit semiconductive, piezoelectric and even photoelectric properties, different forms of stimulation can be converted into an electrical signal.

A criticism of the glial DC transmission hypothesis is that there is no obvious association between the system and perineural tissues. A more recent theory tries to explain the known DC characteristics of the body in the distribution and orientation of collagen, macromolecule fibres within connective tissues. It has been suggested that the DC component of the system may be located within the continuum of liquid crystal collagen fibres which make the bulk of connective tissue which abounds throughout the whole of the body. Ho and Knight¹⁰⁷ argue the system exists more or less independently of the nervous system. The DC circuits have a shared anatomical foundation in connective tissue and accompanying layers of structured water molecules which would allow rapid semiconduction of protons to integrate and maintain all bodily functions. They propose that such a system would constitute a “body consciousness” which interconnects with the central nervous system or “brain consciousness”. Cells are now recognised as being closely electrically and mechanically connected in an integrated ‘solid state’¹⁰⁸ via connective tissue. Ho and Knight propose that liquid crystals make an ideal medium for such intercommunication. They are flexible, malleable, responsive and have orientation being sensitive to orientation or phase transitions in electric and magnetic fields, as well as temperature, shear force, hydration, pH and pressure. Ingber¹⁰⁹ describes the connective tissue system as a “global tensegrity system” integrating and coordinating function in all living systems.

It is difficult to see how such an omnipresent tissue could be organised into such a discrete system without some anatomical evidence having come to light by now. However these models offer fertile ground for speculating and researching mechanisms of electrical and other pulsed

therapies involving lasers and electromagnetic fields. Currents known to be produced by injury are said to be a manifestation of this glial system which is also associated with growth and repair. Electric currents and associated fields have been shown to be fundamental to differentiation and morphogenesis in both plants and animals^{110,111}. All life have mechanisms for varying degrees for self repair and growth; within the metazoans coordinated growth and cell division is dependent on electrical fields. One or two of the more spectacular examples of repair abilities include the regeneration of amputated limbs in newts¹¹¹ and axolotls¹¹², partial regeneration of the forelimb in rats and finger tips in children¹¹³.

There are exciting avenues to follow in the uses of electrical treatments based on manipulating the endemic electrical properties of biological tissues and physiological processes and should herald a transformation in the way that illness is viewed. Unfortunately, like a super tanker on the high seas, it is a long, slow process for medical orthodoxy to change course and navigate new routes. Exactly where TENS fits into this electrical body seascape is currently not clear but we hope that, by introducing some of the concepts to you, it will increase your awareness that there could be more to TENS treatment than 'just' the endorphin effect or more then 'just' the gate control theory.

3. TENS machines and electrostimulation parameters

This chapter is an introduction to the TENS unit, accessories, electrical parameters and modes of stimulation. An in depth examination is provided by other [sources](#)^{1,2,3,4,5,6} and these are recommended for practitioners who are seeking to develop an increased academic knowledge. However, the information provided here is more than sufficient for novice and experienced practitioners alike who are seeking to develop an effective working, practical knowledge of TENS and its clinical applications.

3.1 TENS units and accessories

3.2 Electrostimulation parameters

3.2.1 Waveform

3.2.2 Polarity

3.2.3 Pulse amplitude or intensity

3.2.4 Pulse frequency or pulse repetition rate

3.2.5 Pulse width or duration

3.3 Modes of TENS electrostimulation

3.3.1 High frequency, conventional TENS

3.3.2 Low frequency acupuncture-like TENS

3.3.3 Pulse burst mode

3.3.4 Modulated waveforms

3.3.5 Brief intense TENS

3.3.6 Neuro-electric acupuncture (NEAP)

3.3.7 Acupuncture ear point stimulation

3.4 Some recommendations about TENS units

3.1 TENS units and accessories

There are many different styles and types of TENS units, usually sold as kits with electrodes, leads, battery, gels and manuals, available throughout the world and they are similar in many respects. All TENS units must meet the legal requirements and be licensed or approved in your own country so check before purchasing and using for treatment. In the UK, the design and sale of electrical equipment used for medical treatment is surrounded by a complexity of European Union and British legislation, mainly the Medical Devices Directive 93/94/EEC and Medical Devices Regulations 1994 (SI1994 No.3017) all under the auspices of the Medical Devices Agency (MDA). The primary task of the MDA is to help safeguard public health by working with users, manufacturers and legislators to ensure that all medical devices meet appropriate standards of safety, quality and performance and that they comply with relevant Directives of the European Union.

An additional complication is the 'CE' mark which indicates that an object meets any relevant specific regulations and is fit and safe for its intended purpose. To receive the mark, manufacturers of electrotherapy devices have to provide evidence for any claims for medical efficacy attributed to their product (not necessarily clinical trials) as well as pass safety requirements. The parameters of the electrical stimulation produced by an apparatus must be fully specified. In order to overcome the legislative complications, manufacturers tend not to make medical claims but keep assertion as non medical and simple as possible. Practitioners may be able to bring devices into Europe not bearing the CE mark for personnel use or for use with patients but if the equipment is sold on, then CE mark regulations would apply. Older machines bought before these regulations came into force in 1995 can still be used and resold as long as they have not been modified. These notes are intended to indicate some of the complications arising from the regulations and should not be taken as an authoritative summary.

At the heart of a TENS unit is a battery driven, pulse generator with one or two outlets to leads which are attached to electrodes and applied to

the skin. Typically the maximum current produced is around 60mA. Current passes into the patient via the leads and electrodes. The simplest units will always have an amplitude (or 'volume') control to regulate the flow of current and hence the intensity of the stimulation. A basic requirement which some machines do not have, is a switch to change between specific, identified stimulation frequencies. Many switch between unspecified frequencies and because the frequency of the stimulation can be an important component of treatment, the practitioners must be able to choose specific parameters. With the development of more sophisticated electronic technology, it is now hard to find a simple TENS such as this.

3.2 Electrostimulation parameters

3.2.1 Waveform

3.2.2 Polarity

3.2.3 Pulse amplitude or intensity

3.2.4 Pulse frequency or pulse repetition rate

3.2.5 Pulse width or duration

3.2.1 Waveform

The wave form of the stimulation is the shape of the fundamental wave or electrical stimulation as it would appear on an oscilloscope, for example. Those who consider electrical therapies only in terms of neural stimulation argue that the resistance and capacitance of the tissue alter the shape of the pulse to such an extent that the initial waveform is of no importance. The parameters of waveform will be altered by tissue but to replicate and compare treatment protocols, it is important to know the initial characteristics of the fundamental frequency. The standard waveforms produced by most TENS units is based on a square wave form. These contain odd numbered harmonics at amplitudes close to the fundamental. This means that a treatment given at 80Hz, for example, will include harmonics at 240Hz (x3), 400Hz (x5), 560Hz (x7), 720Hz (x9) etc.

The pulse is designated **square wave** because the current is switched from off to on very quickly. As it is drawn in the diagram, this occupies zero time. Clearly a very small time span must lapse as the pulse is switched on (and off) and the leading (and trailing) edge of the square wave will have an extremely slight slope from the vertical. This is known as the **rise time**. A square wave pulse is the most comfortable for the patient. The fast rise time of the pulse results in minimum sensory stimulation. Wave forms with a slow rise time such as sine waves or saw-tooth (triangular) wave forms can be very uncomfortable. For experimental dental pain, a transcutaneous rectangular waveform was found more effective than sinusoidal or **sawtooth ones**⁷.

If stimulation does not require physical contact with the skin, such as using magnetic fields, then other wave forms, such as sine waves may be used comfortably.

- **Parameter A** is the pulse width and is the length of time during which the pulse is actually switched on.
- **Parameter B** shows the level of **amplitude**, 'strength' or 'volume' of the stimulus.

3

3.2

- Parameter **C** is the **pulse space** ie. the time between successive pulses which varies with the frequency of the pulse.

Most pieces of equipment are driven by a 9V battery and to achieve a suitable voltage for stimulation, this is boosted by a transformer. Careful design is required to avoid adding unwanted or unidentified components to the stimulus because of ringing and other inductive effects via the transformer. Some pieces of equipment produce wave forms similar to that with reverse or over-shoot spikes. Reverse spikes with a potential difference of up to 100V can be measured in badly designed equipment. This has the effect increasing the amplitude of the stimulation significantly and can be very uncomfortable for the patient.

3.2.2 Polarity

Safety and comfort are dependent on wave form, pulse width, and amplitude. Another important characteristic of the wave form which can trigger undesirable physiological responses, if not understood properly, is the polarity of the pulse. The pulse train shown above is a **monophasic** or monopolar wave form.

When two electrodes are applied to the body, one will always be positive with respect to the other. Therefore, if the electrodes are applied bilaterally, one side of the body will receive a train of pulses making it more positive with respect to the other. The side effects are delayed but the overall effect is to set up a left/right imbalance in the body which at best can result in poor treatment response and at worst may exacerbate the existing problem.

Using a **positive monophasic** stimulus could exacerbate the symptoms by compounding the disequilibrium.

To overcome this, a **biphasic** or bipolar pulse is employed. It can be seen that each successive pulse exhibits an opposite polarity. This results in the application of an equal number of positive and negative pulses through each electrode. This would **balance out** any electrical imbalances which may be exacerbated by a monopolar stimulation of the wrong polarity.

Technical information on biphasic waveforms is arguably the most important electrical parameter to consider in assessing the safety and efficacy of pain management using TENS and, therefore, the quality of conventional TENS units.

There are two types of biphasic waveforms produced by TENS units, namely, **symmetrical** and **asymmetrical biphasic** waveforms. There is some confusion and debate between practitioners, manufacturers and suppliers of TENS units on the respective merits of the two.

Symmetrical biphasic waveforms have identical positive and negative phases, with the two phases having the same area and are charge-balanced ie. the amount of charge under the positive portion of the waveform is equal to the amount of charge under the negative portion of the waveform and there is zero net DC flow.

Most units available in the UK are described as asymmetrical with the phases having different areas and not charge-balanced with the duration and magnitude of current flow not equal in both directions resulting in some net DC flow. The flow of current can be sufficient to cause depolarisation like a monophasic pulse train with a build up of charge under one electrode potentially causing skin damage¹ and, as we have seen, the exacerbation of the problem being treated because of the build up of charge. Polarisation also raises the electrode resistance over time, thus reducing the intensity of stimulation⁸.

When tissues are traumatised, the cells become positively charged while the normal cells remain electrically neutral. The positive electric field created by the injured cells inhibits biological processes such as the transport of amino acids and the generation of ATP in the mitochondria of the cell. This results in decreased protein synthesis and calcium intake into the injured tissue and prolongs recovery time. Stimulation with a positive charge or an asymmetrical/monophasic waveform may thus aggravate the pain rather than relieve it and delay the healing process. Neutralisation of this positive charge by a biphasic waveform helps to relieve pain and promote healing by stimulating ATP production.

There is compelling evidence for using charge-balanced symmetrical biphasic waveforms in preference to monophasic or asymmetrical biphasic waveforms (which are really acting as monophasic units) and generally, it is agreed that charge-balanced, symmetrical biphasic waveforms are preferred both for patient safety and comfort and for effective pain management. The production of a zero net DC reduces the likelihood of chemical skin irritation and potential worsening of symptoms.

Whilst it may be true that charge-balanced symmetrical biphasic waveform TENS units are marginally more expensive than other units available in the UK, the benefits for quality patient care and safety and effective pain management are worth the extra investment. This extra investment in UNIT costs ensures a safer electrical stimulation reducing potential side effects and enhancing comfort for the patient in comparison with other TENS units.

In terms of patient comfort, most subjects prefer a symmetric biphasic waveform to a monophasic or asymmetric biphasic waveform stimulation^{9,10}.

We prefer and recommend a balanced biphasic pulsed current unit whenever possible.

3.2.3 Pulse amplitude or intensity

Intensity refers to the strength of the current applied to the patient from the TENS unit. The intensity of a constant current TENS unit may be measured in milliamps (mA). Standard practice is to use a low intensity setting for conventional high frequency TENS and higher intensity setting for low frequency TENS. Amplitude will directly affect patients' comfort. There is a school of thought which supports setting of amplitude at a level which is uncomfortable for the patient. Recent evidence, although indirect, suggests that amplitude windows exist in the same way as frequency windows with no noticeable, 'extra' physiological response occurring if the amplitude is either too high or too low.

Most pieces of equipment are powered by a 9V battery. This voltage is boosted by a step up transformer to achieve suitable voltages for stimulation. Transformers and associated circuitry have to be carefully designed to avoid producing extraneous parameters to the waveform by ringing or other inductive effects. Some equipment produces a reverse or **overshoot** spike into the waveform which has the effect of momentarily increases the stimulation intensity by up to 100V which can be very uncomfortable for the patient. Overshoot spikes are often called asymmetrical waveforms in the technical description of some units.

3.2.4 Pulse frequency or pulse repetition rate

The frequency of a current describes the number of pulses delivered per second and is often written in Hertz (Hz) eg. 2Hz or 100Hz. The alternative method is to describe the frequencies as pulses per second (pps) - 2pps or 100pps and this is the convention we will use.

As we have seen in 2.3, stimulation frequency can have a significant impact on treatment efficacy and biochemical changes within the body. The pulse rate produces discrete packages of information which is not dependent on the intensity of the stimulation.

Square waves also contain odd numbered harmonics at amplitudes close to the fundamental frequency . This means that a treatment given at 80pps (the fundamental, for example, will include harmonics at 240pps (x3), 400pps (x5), 560pps (x7), 720pps (x9) etc.

3.2.5 Pulse width or duration

Pulse width or pulse duration describes the time in microseconds (μsec) taken to complete one section of the waveform usually the positive phase. Typically, this is $200\mu\text{sec}$. Variations of pulse width have no discernible effect on the efficacy of treatment but if they become too long, $>500\mu\text{sec}$, problems related to polarisation, electrolysis, destruction and burning of the tissue under the electrodes can result. It is a standard practice to increase the pulse width as the frequency of the current is reduced, eg. the standard setting for 2pps is $200\mu\text{sec}$ and for 80pps and above $80\mu\text{sec}$. This titration of pulse width to frequency leads to a greater degree of patient comfort during treatment. Pulses wider than 1.0msec do not further enhance nerve activation but increase problems due to polarisation, electrophoresis and tissue heating and limit the pulse rates which can be used⁸.

3.3 Types of TENS electrostimulation

- 3.3.1 High frequency conventional TENS**
- 3.3.2 Low frequency acupuncture- like TENS**
- 3.3.3 Pulse burst mode**
- 3.3.4 Modulated waveforms**
- 3.3.5 Brief intense TENS**
- 3.3.6 Neuro-electric acupuncture (NEAP)**
- 3.3.7 Acupuncture ear point stimulation**

3.3.1 High frequency conventional TENS

High frequency/low intensity stimulation is the most commonly used method of TENS and is the term used to describe the selection and application of specific, high frequency currents to painful/non-painful areas of the body for pain relief. This standard TENS treatment is carried out with the pulse rate set to 60 to 80pps or more and the pulse width settings between 80 and 100µsec. The amplitude/intensity setting should be adjusted until the sensation produced can be described as a steady "buzzing" or "tingling" feeling without sustained muscle contraction.

The strength of stimulation may lessen after a few minutes and the intensity should then be increased as necessary to maintain the original level of stimulation. This method of TENS invokes rapid analgesia, initially via the gating mechanism, but high frequency stimulation has also been shown to release dynorphins, serotonin and cortisol, which also appear to be involved in promoting analgesia and reducing inflammation. Many patients find that high frequency TENS produces the quickest relief from pain, often lasting several hours, even after a short treatment of just one hour. However, others find this analgesia relatively short lived and, as a consequence, may need treatment sessions lasting several hours or even continuous stimulation for adequate analgesia to be maintained.

3.3.2 Low Frequency Acupuncture-like TENS

Acupuncture-like transcutaneous electric nerve stimulation (ALTENS) is low frequency/high intensity stimulation. These are the terms used to describe the selection and application of low frequency currents for short periods of time, usually 30 minutes, to painful or non painful areas of the body for pain relief. This type of treatment can be useful for a range of other symptoms including nausea, vomiting, anxiety, depression, fatigue, hormonal imbalances, migraine, insomnia, withdrawal symptoms, allergic responses.

ALTENS is carried out with the pulse rate setting below 4pps, usually at a recommended setting of 2pps, with a pulse rate setting of 200µsec. These low frequency treatments are adjusted to an intensity that produces visible muscle twitching and may be described as a "tapping" or "pulsating" feeling. [Stux and Pomeranz⁸](#) recommend even stronger stimulation, to a level as strong as the patient can tolerate, in order to achieve maximum release of cortisone and endorphins. Patients find that this type of treatment takes longer, at least 20 to 30 minutes to be effective, but the result of a 30-60 minute treatment may last for a much longer period of time, hours and sometimes days. This method of TENS analgesia appears to invoke the development of opioid peptide mediated (endorphin) analgesia, is slower acting than conventional TENS but with a longer lasting analgesic effect.

The sites of electrode application may or may not be at specific acupuncture points but the application of these frequencies at specific acupuncture points appears to enhance their effect to the same degree, or even higher, than one would expect from Traditional Chinese Medicine (TCM) acupuncture [approaches¹¹](#). However, not all TENS units are suitable for this treatment and practitioner advice is usually necessary before the patient purchases a suitable unit for ALTENS treatment at home.

3.3.3 Pulse Burst Mode

Some TENS units have other settings such as a pulse burst (B) mode, which combines elements of the two modes as described above, and may be used when either conventional TENS or ALTENS do not give adequate pain control.

Burst TENS was developed by Eriksson and Sjölund¹² for the treatment of chronic pain. They found that high intensity trains of electrical stimuli delivered at a low frequency through acupuncture needles, was very uncomfortable for patients. However they could tolerate the stimulus intensity required to produce the desired strong muscle twitches much better than when bursts were delivered through the needle because the pulse trains were more comfortable. It has been suggested that the technique prevents accommodation to stimulation as well as improving patient tolerance but there is little published evidence to support this although Humphreys¹³ found that some patients consider burst mode more comfortable than the low frequency rate mode. Setting the pulse rate to 80 pps or above followed by selection of the 'B' burst setting produces a treatment current which will 'burst' at 1 second intervals with 80 pulses (called the internal frequency) in each second followed by a one second rest and repeated. This 'B' burst setting means that some of the benefits of both modes may be expected, ie. endorphins from the 1pps and dynorphins, serotonin and cortisol from the high frequency stimulation together with appropriate gating effects in the dorsal horn of the spinal cord.

3.3.4 Modulated waveforms

Another feature available on some TENS units is a modulation mode, which varies either/or both the pulse width and pulse frequencies in a cyclical fashion. Many patients have found these modes helpful for increasing pain control, providing extra comfort and for relaxing muscles when the effects of conventional or acupuncture-like TENS have not been found effective or have diminished over time.

3.3.5 Brief Intense TENS

High pulse rate, brief, intense stimulation may be considered for some procedures such as surgical debridement, rehabilitative manipulation and colonoscopy. The recommended **settings¹** are pulse rate of 150pps, pulse width 150μsec at sufficiently high intensity to produce muscle fasciculations or to tolerance for 15min or less with short rest periods of 2-3min.

3.3.6 Neuro-electric acupuncture (NEAP)

This is the most modern technique available and uses surface electrodes, as supplied with conventional TENS units, to apply electrical stimulation to body acupuncture points. The treatment usually lasts 30min once or twice a week but can be daily for drug withdrawal and/or home use depending on the problem under consideration. Some special units are available but some TENS units, if they produce a balanced biphasic waveform and have a sufficiently low frequency (pps) range also are suitable for this treatment. Many other units are not. Further details can be found in Section 7.

3.3.7 Acupuncture ear point stimulation

Electro-auriculotherapy is a method of treating acupuncture points in the ear using an electric probe stimulator. This is an important part of modern electro-acupuncture treatment. There are acupuncture points on the ear which are said to correspond to different parts of the body and electrical treatment in the clinic and/or manual acupressure at home is often highly effective in the treatment programme. There is minimal discomfort from the probe stimulator and the treatments are safe and effective. There are many electrical point stimulators currently available but they are all very similar in action. The main difference is the high cost of some units, which may be two or three times or more than equivalent suitable and effective models. These are also suitable for home use after appropriate instruction by a practitioner.

3.4 Some Recommendations About TENS Units

There are some basic attributes which remain common to all TENS units and these will be considered first followed by an examination of more specialised parameters to be found in more expensive and sophisticated TENS units.

A basic TENS unit as described above, has a pulse generator contained in a high impact plastic case and comes with a single output to a pair of leads. The unit is controlled by an ON/OFF switch which may function as an intensity control. Stimulation is often at a fixed frequency ranging from 16pps to 80-100pps.

More sophisticated dual channel TENS units, usually produce a biphasic waveform and have a range of functions which may include controls

- for selecting different frequencies
- altering the pulse width
- a mode selector
- a timing device
- individual output controls to two or more leads.

Output leads are lightweight and flexible with a plug at one end to insert into the TENS unit and a pin at the other which is inserted into an electrode. Electrodes may be made of carbon rubber with a vinyl coating which require tape for attachment to the skin or self-adhesive electrodes which are easy to apply and do not require fixing by tape. These are becoming the more usual method of application.

As indicated earlier there are many models of TENS units available throughout the world with either single and double channel outputs, priced to suit most practitioners and patients. However, it would seem advisable to look for a unit, which meets most if not all of the following parameters:

1. a biphasic, balanced waveform in preference to an asymmetrical biphasic or monophasic one

2. a range of frequencies from 2pps to 200pps at least
3. a pulse width range from 80-200μsec
4. each channel should have independent current intensity control
5. should have a continuous and a pulse-burst facility
6. should preferably have a timer with continuous and 30min setting
7. should be lightweight and easily attached by a clip to a trouser or skirt belt
8. controls should be easy to operate and preferably protected from inadvertent resetting by movement and clothing etc. Make sure that patients are able to operate switches and knobs. These are often very small and could be difficult with arthritic hands for example
9. should be priced at no more than £100 sterling, have at least a one year warranty, and accessories including self-adhesive electrodes should be easily available.

4. Treatment design, clinical application - selecting appropriate parameters

4.1 Introduction

4.2 Acute and subacute pain

4.3 Chronic pain

4.4 Still having problems?

4.5 Uses in some specific areas

4.5.1 Labour and delivery

4.5.1.1 Some background

4.5.1.2 Some practicalities

4.5.2 Postoperative pain

4.5.2.1 Some background

4.5.2.2 Some practicalities

4.5.3 Control of vomiting and nausea

4.5.3.1 Some background

4.5.3.2 Some practicalities

4.5.4 Dymenorrhea

4.5.4.1 Some background

4.5.4.2 Some practicalities

4.5.5 Dentistry

4.5.5.1 Introduction

4.5.5.2 Pain control

4.5.5.3 EDA technique using electrodes in the mouth

4.5.5.4 Other uses in dentistry

4.1 Introduction

Currently there is insufficient evidence from comparative studies to determine the optimal TENS mode for a given pathology or diagnosis associated with painful and non painful problems. There have been literally thousands of TENS studies published over the past thirty years. Most of the studies are very poor quality, which precludes a realistic assessment of the benefits of the various forms of TENS treatment. However, from our own research, systematic reviews and clinical experience over the past twenty years we would suggest the following simplified, generalised treatment models for acute, subacute and chronic pain. Start simply and if the response is poor then start augmenting treatment with the range of extra modalities which may be available on the TENS unit. There seems little doubt that TENS, after more than thirty years of use, can be an effective method of pain management for most people, but success does not always come easy, and it is far too easy to abandon the treatment rather than to persevere with different parameters.

No reduction in analgesics should be made until a good level of pain control has been established using an appropriate pain measurement tool for acute or chronic pain. Often patients report that they are decreasing their analgesics of their own fruition once the TENS procedure starts to become effective. The use of other conventional and unconventional techniques such as cold packs, massage, acupressure, aromatherapy, relaxation etc. should also be encouraged during the treatment period.

4.2 Acute and subacute pain

Treat with low frequency, high intensity stimulation using a frequency of 2pps, a pulse width of 200 μ sec, at an intensity as strong as the patient can withstand comfortably for 30 minutes. This treatment may be repeated three or more times daily. If acute pain does not respond within a day or two then use high frequency stimulation with settings as in 4.3.

4.3 Chronic pain

DM Long, a pioneer in TENS therapy and research, has observed that "it is probable that transcutaneous electrical stimulation represents the single most effective physical entity yet produced in the management of chronic pain"¹. Whilst we would agree in principle with this statement, it is not always as easy in practice to determine the optimum treatment regime. The main reason for failure to obtain adequate pain relief for example would appear to be an inadequate number of treatments; there is evidence that TENS effectiveness increases slowly, and that large doses need to be used². Whilst some patients respond rapidly and obtain relief from pain after just a few treatments, others need to persevere for at least one month having one or more treatments each day before abandoning the treatment. During this time it may also be necessary to try out different frequencies and modes.

The initial treatment regime should be conventional high frequency low intensity stimulation at a frequency of 60-80pps, a pulse width of 80-100µsec and an intensity setting which produces distinct paræsthesia (numbness or tingling with pain relief) in the area of pain. Apply for one hour in the first instance. This may be repeated three or more times each day depending on response. If little or no response, try longer treatments and if this is not effective use continuous treatment. Long term treatment may be indicated and at least a month of continuous daily treatment should be considered before trying different electrical parameters or alternative treatments².

SUMMARY

4.4 Still having problems?

If your patient is still having difficulty getting pain relief after going through this CD manual again, and the user manual which came with the TENS unit then the following tips will help you to maximise the benefits from the unit. Some clients find that it takes two or more treatments a day, sometimes for several hours for each treatment, for several days, to achieve the pain relief they are looking for. Even professionals do not always get instant pain relief for their clients! Do not abandon TENS treatment after just a few treatments but keep using it, for two or more weeks at the least, as the effects tend to be cumulative. The most common cause of failure to achieve pain relief is too few treatments, so make sure you have given the treatment unit a really good trial and remember, the longer your patient has been in pain then it may take longer to reduce it and more treatments will be needed. It may be necessary also to adjust the pulse rate/mode and/or the electrode placements to gain the most satisfactory outcome.

Instigate changes one at a time.

- Do not advise your patient to stop taking their usual medications when beginning their TENS treatment, but they can discuss reducing the dosage with their medical practitioner as pain decreases.
- If the pain becomes worse, either during or after the treatment, this is due usually to using the incorrect pulse rate. Try a different one and if this does not help move the electrodes to another position and repeat until you obtain satisfactory pain relief.
- Make sure the electrodes are firmly in place at all times, in good condition, if self adhesive electrodes, with plenty of gel.
- Enthusiastic tea or coffee drinking may reduce the analgesic effect of TENS, so advise decreasing tea and/or coffee intake by half and drink water or fruit juices instead.
- Try moving the electrodes to other positions eg. over the painful area or surrounding the painful area or placed on the opposite side of the body or limb to improve the response.
- Advise your patient to gently exercise the painful area if possible

whilst using the TENS unit and then applying a cold pack (from the refrigerator NOT out of the freezer) to the area of the pain for 10min at the end of the treatment.

- Don't be afraid to experiment with the different pulse settings to find the treatment which gives the best result, but give each change several days to work before changing to another one.
- Experiment with different frequency settings bearing in mind the following guidelines:

high pulse rate settings (above 10 and usually 80, 100 or more pps) on continuous mode (C) should be felt as a tingling sensation and these treatments may need to be applied for at least one hour at a time and sometimes worn for several hours continuously, for at least 2 weeks before changing to another setting;

low pulse rate settings (below 10 and usually 2 or 3) on a continuous mode (C) should be felt quite firmly, almost like a pulsing sensation, at 2pps for 30min treatment once or twice a day is usually sufficient once the pain is under control. The treatment could be repeated 90min after the first one to enhance pain control.

If still unsuccessful, use different pulse rates during each successive treatment eg. 30min on a high rate and 30min on a low rate.

- If available, try a pulse burst treatment by selecting B on the TENS unit and 100 on both the pulse rate (H) and the pulse width (L). Pulse burst mode should be tried using 100pps burst at 1sec intervals or similar settings depending on the parameters of the TENS unit being used. Treatment sessions should last for 30min and can be increased to one hour or more if necessary. Treatment should be tried for at least 14 days before abandoning the treatment if there is no response.
- If the unit has an M setting (Pulse or Pulse width modulation) also try this setting again for 30min sessions or longer if necessary.
- If the back pain is being treated try placing one electrode over the most painful area and the other electrode on the opposite side of the spine. Try placing the electrodes with only 2.5cm between them

4

4.4

on either side of the midline of the spine.

SUMMARY

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4.5 Uses in some specific areas

4.5.1 Labour and delivery

4.5.1.1 Some background

4.5.1.2 Some practicalities

4.5.1 Labour and delivery

4.5.1.1 Some background

Equipment has had to be modified to be used for pain control during labour because the apparatus sometimes interfered with the foetal monitoring equipment and required signal filtering. Some obstetric TENS units have an extra switch which is operated by the patient during contractions to switch either between different pulse rates or to increase pulse intensity.

There is limited evidence that TENS is effective in controlling acute pain during labour. Nesheim³, in a study involving 70 women randomised into two groups receiving TENS and mock stimulation, found no difference between the two groups in the degree of pain relief and no reduction in the need for analgesics which could be ascribed to the use of nerve stimulation. Similarly other studies^{4,5,6,7}, concluded that TENS is ineffective as a routine method of pain relief in labour although Thomas and colleagues⁴ found moderate benefit for those with severe back pain and Chia⁶ found TENS useful during the early stages of labour up to 5/6cm dilatation. Robson⁸ also found TENS especially effective for back ache during labour. TENS had been successfully used on acupuncture points to induce uterine contractions in post term women although none of the women started labour without amniotomy⁹.

Uncontrolled studies have reported moderate to good pain relief^{10,11,12,13,14} particularly during the first stage. Another uncontrolled study concluded that TENS is an effective treatment for use in labour and delivery with no adverse effects on mothers or newborns, reduced the duration of the first stage of labour and the amount of analgesic drug administered¹⁵. In a series of studies^{14,16,17}, Bunsden and colleagues found TENS to be useful in controlling back pain but not suprapubic pain and they established that the technique had no adverse effects on the neonate. However, a randomised, controlled unblinded study involving 34

participants found TENS less effective than intracutaneous sterile water injections for relieving low back pain during labour¹⁸.

In a study described as double blind, involving 100 primigravidæ and 50 women in their third labour, no difference in pain concept or relief was found between the active TENS and the 'dead machine' TENS users. 12 and 13% of primigravidæ and 48 and 39% of the multipara women completed labour without requiring other analgesia. However, the evident consumer satisfaction for TENS suggested the treatment has a part to play in pain control during labour¹⁹. In a comparative study of 170 primigravidæ using TENS, entonox, pethidine + promazine and lumbar epidural, the same authors found that 96% of the 50 using TENS achieved partial pain relief and 82% required additional analgesia. Both studies concluded that the use of TENS during labour required machines specifically to cope with labour pain²⁰. Lee and colleagues found no clinical differences between 3 groups of women receiving active TENS treatment, 'dead machine' treatment and no treatment at all in a non randomised study²¹. TENS was found not to augment combined spinal epidural (CSE) analgesia in a randomised, double blind trial with 40 parturients undergoing uncomplicated deliveries, requesting analgesia who received a standardised CSE with either an active or inactive TENS unit²². van der Spank et al.^{22a} similarly found no statistically significant difference between the experimental TENS group and the control non TENS group in incidence of epidural analgesia.

Using TENS after caesarian sections does not decrease the use of narcotic analgesics but may help with the control of pain around the incision^{23,24}.

A recent systematic review²⁵ of 8 randomised, controlled studies involving 712 women, 352 receiving active TENS and 360 acting as controls concluded that the evidence for reduced pain using TENS in labour was weak. Additional analgesic interventions may be less likely with TENS, but that this may be due to inadequate blinding causing over

estimation of the effects of treatment. The Canadian Coordinating Office for Health Technology Assessment has concluded that there is little evidence for other than a limited use of TENS in a wide range of settings including labour ²⁶. However there is a lot of anecdotal evidence favouring the use of TENS in labour and many women gain great benefit from not having to use a narcotic and avoiding the possible side effects on themselves and their new born baby.

4.5.1.2 Some practicalities

Despite the paucity of convincing data, TENS is commonly offered for pain control during labour and many women find it a successful technique for them, often producing a decrease in the use of narcotic analgesics. In the UK, midwives have been able to advise and instruct women in the use of TENS during labour. Walsh²⁷ suggests the following electrode placement sites for labour pain as one pair of electrodes (large 32mm x 90mm) at T10-L1 level and a second pair (standard 50mm x 50mm) at the level of S2-S3. Continuous output at 80-100pps is used during contractions and the burst output between contractions.

A booster control button is usually available on dedicated obstetric TENS units which allows the user to switch (surge) easily between the burst and the continuous mode during contractions. Some machines switch between pulse repetition rate and others increase pulse intensity. The switch is usually used during contractions. If the switch increases pulse repetition rate then women tend to keep the unit switched to the higher frequency as contractions get stronger.

Treatment should be started as soon as possible once contractions have started although using leg acupuncture points, successful pain control can be achieved starting as late as 7cm dilatation²⁸.

Better pain control can be achieved using acupuncture points. Using surface electrodes, particularly large electrodes, obviates the need for detailed knowledge of the position of the points; as long as the practitioner knows the approximate location, then the current will follow the path of least electrical resistance and 'find' the point. The most useful points to use are St36, Sp6 and Liv3 which are on the leg. The point LI4 has been advocated but women find hand points restricting especially with an iv. infusion. In many ways, using TENS on the leg is more comfortable for the woman. Conventional wisdom has it that treatment has to be bilateral. This means that wires etc. could get in the way of the midwife and could hinder the woman if she wants to walk around. It is our experience, however, that

a pair of electrodes need be attached to **one leg only** using St36 and Sp6 or Sp6 and “extra” point **Neima(see28)**.

- St36 is located between the heads of the fibia and tibia, 3 finger breadths distal to the lower edge of the patella;
- Sp6 is on the posterior edge of the tibia, three finger breadths proximal to the highest point on the medial malleollus;
- Neima is located one hand width below the medial epicondylar ridge of the tibia.

Treatment should be started before 4cm dilatation although multipara have been found to benefit as late as 7cm dilatation. The initial stimulation frequency should be as low as possible and this can be increased as the labour progresses.

Treatment should be continued until delivery and maintained if episiotomy is required.

4.5 Uses in some specific areas

4.5.2 Postoperative pain

4.5.2.1 Some background

4.5.2.1 Some practicalities

4.5.2 Postoperative Pain

4.5.2.1 Some background

TENS has been used to help control pain after a range of surgical procedures eg. hand and foot surgery, coronary artery bypass graft (CABG), hernia repair, appendicectomy, cholecystectomy and thoracotomy, gynæcological procedures, arthroplasty. Any decrease in the requirements for narcotic is to the good of the patient because of the possible side effects including respiratory depression, sedation, orthostatic hypotension, urine retention and nausea. There is also evidence that TENS decreases postoperative morbidity such as ileus, atelectasis, pulmonary function, speeds up wound healing as well as reduces the length of stay in intensive care. TENS is often popular with patients. The published data on the efficacy of TENS in this context is very mixed both in outcome and quality. However, some years ago the Office of Health Technology Assessment of the Public Health Service in Canada found TENS to be an accepted alternative to conventional methods of treatment for acute post surgical incision pain²⁹.

Studies have tended to concentrate on two connected positive indications for use of TENS, measuring either the degree of pain control using various scales such as the visual analogue scale and/or the decrease in the use of analgesics after operations. In their review of the use of TENS to control postoperative pain Carroll and colleagues³⁰ identified 17 reports on randomised trials of which only two, they judged, concluded that TENS was beneficial; in 17 out of 19 non randomised controlled trials, it has been concluded that TENS had a positive analgesic effect.

No significant decrease in the requirement for analgesics has been reported for a range of operations including cholecystectomy^{31,32,33}, orthopædics including arthroplasty^{34,35,36}, inguinal hernia repair³⁷ and thoracotomy³⁸. On the other hand, a significant decrease in analgesic use had been found in a equally wide range of studies with an equally wide range of robustness. Solomon³⁹ in an uncontrolled study on a wide

range of surgical operations, recorded a decrease in narcotic use especially for patients who had not used narcotics prior to their operation. Sodipo found a decrease in a prospective controlled study⁴⁰ as did Pike⁴¹ in a randomised controlled study on pethidine use following hip replacement and Navarathnam in post cardiac surgery patients⁴². Decrease in narcotic use had been attributed to placebo and/or personality^{43,44,45,46}.

Perhaps some of the more convincing evidence on the efficacy of TENS has come from a series of experiments comparing electrostimulation with different parameters and siting of electrodes near the incision and on acupuncture points on groups of 100 women undergoing hysterectomies or myomectomies. Wang et al.⁴⁷ using electrostimulation simultaneously at two sites, an acupuncture points (TAES) and both sides of the incision. The point used was LI4. They randomly assigned women to one of four analgesic regimes:

- group I received patient controlled analgesia (PCA),
- group II PCA + sham TAES (no electrical stimulation),
- group III PCA + low intensity TAES,
- group IV PCA + high intensity TAES.

The TAES frequency was set in the dense and disperse mode, with stimulation of the hand and incision alternated between 2pps and 100pps every 6sec at both high and low intensities. Stimulation was for 30min every 2h. Those receiving high-intensity TAES decreased their Hydromorphone requirement by 65% and also reduced the duration of PCA and incidences of nausea, dizziness and itchiness. TAES at low intensity decreased Hydromorphone requirement by 34% and this compared with a 23% decrease in the sham TAES group. Unfortunately, the experimental design does not allow the contributions of stimulation at the incision and at the acupuncture point to be assessed separately.

Chen and colleagues⁴⁸ also randomly assigned women to one of four postoperative analgesia groups:

- group I sham TAES (no electrical current) bilaterally at the acupuncture point St36,
- group II TAES on the shoulder at a sham, 'neutral' point,
- group III dermatomal TENS at the level of the surgical incision,
- group IV TENS bilaterally at the acupuncture point St36.

The frequency of TENS/TAES was set in the dense and disperse mode of 2 to 100pps and high intensity. In the first 24h, the analgesia requirements in groups III and IV decreased by 35% to 39% compared with group I control sham, dead box group and group II sham acupuncture point. The authors concluded that electrostimulation in the dermatome along side the incision and at the acupuncture point St36 were equally effective in decreasing the demand for postoperative analgesia and also in reducing side effects such as nausea and dizziness due to the analgesic; both were more effective than stimulation at the 'neutral' point on the shoulder.

Finally in this series, Hamza and colleagues⁴⁹ in a randomised, controlled study using mixed frequency (2pps and 100pps) stimulation decreased morphine requirements by 53% compared with the control group; low frequency(2pps) and high(100pps) frequencies produced 32% and 35% decreases, respectively. All three "active" TENS groups reduced the time that patients needed to control their analgesia, as well as the incidence of nausea, dizziness and itching. Electrodes were positioned in the dermatome corresponding to the surgical incision.

It seems that TENS at high intensity (9-12mA) and pulse rates in the range 2-100pps can significantly reduce the demand for analgesia after lower abdominal operations in women. Currently, there is no clear evidence that using electrical stimulation at acupuncture points produces better results than placing electrodes along side the incision; in this context both seem to be equally effective in reducing the demand for analgesics. However, using acupuncture points does have the added advantage of being distant from the wound obviating difficulties around sterilisation and access to electrodes should there be any practical difficulties.

4.5.2.2 Some practicalities

The general approach to using TENS to help control postoperative pain is to use sterile, disposable electrodes placed parallel and approximately 1cm from the incision [Walsh²⁷](#). Electrodes should be positioned as soon as practicable after surgery with usual precautions about ensuring good electrical contact with the skin, wires tidy and secure. Stimulation should begin within two hours, frequency 2-100pps, at high intensity (9-12mA) without causing discomfort. There are a number of different possible configuration for electrodes, (see fig) parallel, crossed pairs, [unilateral pairs⁵⁰](#). The evidence that any one configuration confers any advantage is scanty so if in doubt, keep it simple. For procedures involving joints, however, more complicated arrangements may be preferable. [Harvie⁵¹](#) has used TENS after a number of different procedures involving knee surgery and advocates placement of electrodes over the medial and collateral ligaments.

The electrodes can be left in place with continuous stimulation for 48-72h and use for up to 7 days has been reported.

4.5 Uses in some specific areas

4.5.3 Control of vomiting and nausea

4.5.3.1 Some background

4.5.3.2 Some practicalities

4.5.3 Control of vomiting and nausea

4.5.3.1 Some background

A common side effect of using narcotics for the control of postoperative pain is nausea. A number of studies into the use of TENS for postoperative pain control in conjunction with narcotics have noted that emetic symptoms are lessened by the electrical stimulation^{47,48,49,52}. In these cases, control of nausea is secondary to the main aim of the study which was to investigate pain control and no special procedures were carried out to investigate nausea.

However there have also been studies carried out specifically to investigate postoperative nausea. This involves bilateral stimulation at the acupuncture point Pericardium₆ (P₆).

In a meta-analysis of some 19 randomised trials of non pharmacological means of controlling postoperative nausea and vomiting, techniques which included acupuncture, electroacupuncture, acupoint stimulation, acupressure as well as transcutaneous electrical nerve stimulation, Lee⁵⁴ found these techniques were equally effective as commonly used antiemetic drugs in preventing vomiting after surgery. They were more effective than placebo in preventing nausea and vomiting within 6h of surgery in adults, but there was no benefit for children.

In a study of 103 women undergoing hysterectomy⁵⁵, TENS at P₆ was applied bilaterally 30-45min before induction of anaesthesia in 51 patients and continued for 6h postoperatively. The 52 patients in the control group were treated exactly in the same way but with a 'dead machine'. Incidence of vomiting was assessed blindly 2h, 4h, 6h, and 8h postoperatively. The incidence of postoperative vomiting was significantly less in the TENS group. While modern antiemetics can control vomiting, they are relatively ineffective against nausea. Other investigations have concentrated on the control of nausea accompanying chemotherapy using cisplatin⁵⁶. To evaluate the efficacy of a branded TENS unit as part of standard antiemetic therapy during treatment with cisplatin in gynaecological oncology, 42 women were

enrolled in a randomised, double-blind, placebo-controlled parallel-subjects trial with a follow-up crossover trial. The results indicated that the severity of nausea was significantly lower during days 2 to 4 with active TENS treatment. Patients averaged less than one episode of vomiting daily in each cycle. The authors found this branded treatment to be an effective adjunct to standard antiemetic treatment in this context.

The other area in which TENS on the wrist has been used as an antiemetic treatment is for early morning sickness during pregnancy. Acupressure at P6 as well as acupuncture and electroacupuncture have been used extensively in this context. Evans⁵⁷ recruited 23 women with nausea and vomiting in the first 14 weeks of pregnancy in a randomised, crossover study comparing an active stimulation unit and an inactive placebo unit using the P6 point on the wrist and found that the treatment can effectively improve nausea and vomiting during pregnancy compared to a placebo device.

4.5.3.2 Some practicalities

Stimulation is applied to the acupuncture point **Pericardium6 (P6)**. This point is located 3 finger breadths above the proximal crease of the wrist at the lateral edge of the palmaris longus muscle. Stimulation at 2.5pps or 10pps appears to be satisfactory and to be effective has to be given before the opioid treatment is **started****see 53**. Treatment can be as often as required for the various situations where it may be used.

4.5 Uses in some specific areas

4.5.4 Dysmenorrhea

4.5.4.1 Some background

4.5.4.2 Some practicalities

4.5.4 Dysmenorrhea

4.5.4.1 Some background

TENS can be used to help control the pain accompanying dysmenorrhea but, as is common with so many claims associated with TENS, there is a paucity of robust studies indicating just how useful the technique may be.

Various uncontrolled studies have indicated that TENS can bring significant pain relief. Milsom⁵⁸ contrasted the effects of high-intensity transcutaneous electrical nerve stimulation and oral naproxen (500 mg) on intrauterine pressure and menstrual pain. It was claimed that TENS induced prompt pain relief when applied segmentally but without any significant changes in uterine activity. In a study with 61 women, Kaplan and colleagues⁵⁹ used TENS for two cycles and 90% of participants reported good to moderate pain relief. Similar results were found when they used a branded TENS machine on 102 nulliparous women, who had been treated with a range of analgesics⁶⁰. Marked pain relief was reported by 58 patients (56.9%) and moderate relief by 31 (30.4%). These subjective findings were supported by the fact that the same number of patients either stopped or reduced their use of analgesics. Lewers⁶¹ compared a placebo medication with low frequency, high intensity TENS in 21 women and found an average pain relief of at least 50% immediately after TENS treatment.

In an attempt to investigate the rôle of opioid peptides in TENS, Lundeberg⁶² used TENS at high (100pps) and low frequency (2pps) and compared the results with placebo TENS in 21 women. High frequency TENS produced pain reduction exceeding 50% of its original intensity in 67% of the women compared to 33% receiving low intensity treatment and 24% receiving the placebo. In 4 out of 6 volunteer patients, the relief of pain obtained with low frequency TENS was counteracted by naloxone, whereas the relief experienced with high frequency TENS in the same patients was, in general, unaffected by naloxone indicating a possible rôle of opioid peptides in low frequency TENS.

In a stronger study, Dawood and colleagues⁶³ carried out a randomised four-way crossover study, with 32 women with primary dysmenorrhea treated with TENS (100 pps with 100µsec pulse width) for two cycles, placebo (sham) TENS for one cycle, or ibuprofen 400mg four times a day for one cycle. Participants adjusted the stimulation amplitude to a comfortable level. The rescue medication was 400mg ibuprofen as needed, up to 1600mg day⁻¹. Compared with placebo TENS or ibuprofen-treated cycles, significantly more subjects receiving TENS did not require rescue medication or required less backup ibuprofen after starting treatment at the onset of symptoms and during menstruation. Typically, TENS significantly delayed the need for ibuprofen by 6h, compared with 0.7h using ibuprofen alone. The technique provided good to excellent subjective pain relief in 42.4% of subjects, compared with 3.2% with placebo TENS; active TENS also significantly reduced diarrhoea, menstrual flow, clot formation and fatigue compared with placebo TENS.

4.5.4.2 Some practicalities

Use the **electrode placement** as shown and, from the limited data available, stimulation at 100pps appears to give the optimum result. If this is not satisfactory try low stimulation frequency before going through the options in **4.4.**

It does seem that TENS could serve as a main treatment modality for women who suffer from primary dysmenorrhea and do not wish to or cannot use the usual drugs, providing moderate to good pain control in 40-90% of women. In addition, the technique can be used as an adjuvant to conventional analgesics in severe cases.

4.5 Uses in some specific areas

4.5.5 Dentistry

4.5.5.1 Introduction

4.5.5.2 Pain control

4.5.5.3 EDA technique using electrodes in the mouth

4.5.5.4 Other uses in dentistry

4.5.5 Dentistry

4.5.5.1 Introduction

The development of transcutaneous electrical nerve stimulation has seen a number of different applications in **dentistry**^{64,65,66} some involving a complex mix of electrode placements on the temples, in the mouth and using pertinent acupuncture points on the **hand**⁶⁶. This has lead to more specialised techniques under the collective term of Electronic Dental Anæsthesia (EDA) and carrying various brand names for controlling pain particularly for restorations. Using EDA, pain control is achieved by applying electrical stimulation directly to the gum of the offending tooth with significant success in the preparation for fillings and for **root canal work**^{67,68,69}. The technique has been especially useful for patients who fear needles or are allergic to conventional injections, have hypomineralised teeth or bleeding disorders. A rôle for TENS has been found also in the treatment of bruxism, chronic orofacial pain and temporomandibular joint problems.

4.5.5.2 Pain control

Particular attention has been paid to the use of TENS or EDA for pain control in children. Abdulhameed et al.⁷⁰ investigated the effect of TENS on tooth pain threshold and comfort of oral soft tissue in 30 children in a double-blind, crossover study. Tooth pain threshold was measured before and after 8 minutes of electrical or sham stimulation. Comfort of oral soft tissue during placement of a rubber dam clamp was evaluated 3min after electrical or sham stimulation was begun using a visual analogue scale. Heart rate was measured before and immediately following placement of the clamp. Electrical stimulation significantly increased tooth pain threshold and reduced the cardiovascular stress response without altering comfort levels during placement of the clamp. teDuits⁷¹ and Oztas⁷² found no significant difference between EDA and local anaesthesia in the perception of pain in 6 to 12 year olds undergoing deep cavity preparation. This has been dismissed as a placebo affect by Modaresi⁷³; in a study involving 30 children allocated at random to three groups to receive EDA, a placebo EDA or anaesthesia by oral injection for occlusal restorations, he found that treatment time was shortest in the oral injection group and no significant correlation with any measure of pain, disruptive behaviour or depth of cavity. He concluded that EDA was no less effective than injected anaesthesia, but probably worked by distracting the patients because it was no more effective than a placebo EDA. However, Harvey and colleagues⁷⁴ in a randomised study involving some 20 patients, aged 8-14 years, treated for Class I amalgam restorations in mandibular first permanent molars, used TENS in a double blind protocol. The control group received no analgesia and it was concluded that there was a statistically significant decrease in the pain perceptions of patients receiving TENS.

Perrson⁶⁸ made a direct comparison of injected local analgesia and EDA using pairs of homologous molars, which were destined to be removed eventually for orthodontic reasons, in 20 subjects aged 11-16 years and. A standard cavity was cut through the dentine 2mm into the pulp, the cavity lined and filled with glass ionomer cement. One side was treated with 2% Xylocaine-adrenaline and the homologue with

EDA. One month later a partial pulpectomy was performed on each tooth removing at least 3-4mm of pulp. Homologous pairs of teeth make excellent experimental material for comparative observations because the left and right version in the same mouth are be considered to be the same and direct comparisons can be made of procedures carried out on the left and right version.

After each procedure, the young volunteers completed a pain control questionnaire. Few of the young subjects reported any discomfort at the induction of either form of analgesia. The anæsthetising qualities of Xylocaine were found to be superior to EDA because five treatments in the EDA group and one in the conventional group reported unacceptable pain. However, it should be stressed that no pain or minor acceptable pain was recorded in nineteen treatments in the injected group and fifteen in the EDA group - pulpectomy is one of the most painful dental procedures.

These results led Persson and colleagues to conclude that in particular situations, EDA must be looked upon as a good adjunct in dental care. This seems to be the general conclusion from most of the published studies on EDA. Particular areas where it could be used is during the treatment of hypomineralised teeth, for needle-phobic patients and where allergy and bleeding is a problem with conventional local analgesia. A significant advantage using EDA which patients enjoy is the lack of numbness in soft tissues once the unit is turned off after use.

Using TENS with adults during surgical procedures has produced a mixed range of published results. Hansson & Ekblom found TENS at 2pps and 100pps to be totally ineffective in controlling pain during pulp surgery, abscess incision or tooth **extraction⁷⁵** although the technique was more effective in controlling orofacial pain prior to **surgery⁷⁶**. On the other hand, it has shown electrical stimulation to be as effective as 300-600mg acetaminophen with 30-60mg codeine and indicating a use for patients who cannot be given **medications⁷⁷**. **Clark and colleagues⁷⁸**, in a double blind study to evaluate patient comfort, satisfaction and pain control as judged by the operator during a range

of dental procedures including restorations, tooth extractions, root planing, pulp extirpation recorded an overall favourable rating of 71.8% by the experimental group compared with an overall 8.5% favourable response in the placebo group. Yap and Ho⁶⁹ found that for 30 patients in their study each with two teeth being randomly restored under either electronic or local anaesthesia, 93.3% of the participants preferred electronic anaesthesia despite the fact that local anaesthesia was perceived to be significantly more effective by both patients and dentists.

Wilder-Smith⁷⁹ studied the effects of TENS at various stimulation frequencies on pulpal sensitivity to electrical vitality testing and to cavity preparation. TENS reduced pulpal sensitivity to electric vitality testing by approximately 14% with no significant differences between stimulation frequencies. During cavity preparation, TENS eliminated or minimised pain for 67% of treatments, the best results being obtained at 99pps, the highest frequency investigated. Patients preferred high frequency TENS because of the accompanying sensations of warmth and relaxation.

4.5.5.3 EDA techniques using electrodes in the mouth

To achieve EDA, adhesive electrodes are stuck on the lingual and buccal surfaces of the gum so that the current flows through the root of the tooth under treatment.

Modified rubber dam clips have also been used successfully. These clip onto the teeth to be operated on along the line of the gingiva. If one tooth is to be anæsthetised, a clip is applied to that tooth and the other lead has to be attached to another electrode, such as one which the patient can hold, to complete the electrical circuit. A pair of clips can be used to anæsthetise the group of teeth between the electrodes, in which case a hand held electrode is not necessary. Unlike the adhesive electrodes, the clips can be sterilised.

Stimulation at 80Hz biphasic, square-wave is used. Correct electrode placement along the line of the gingiva is important. The patient controls the strength of the stimulation and is invited to turn up the amplitude until a strong but comfortable "fizzing" was felt on the gum and tooth. This sensation diminishes after 60sec or so and the patient increases amplitude to restore the fizzing. Usually this fades again after 30sec, amplitude is increased again, fades after 15sec, is restored and analgesia achieved. The amplitude can be increased again, if necessary, during the operation.

4.5.5.4 Other uses in dentistry

TENS has been used to reduce the discomfort of inferior dental block injections^{80,81} but appears to be unhelpful during sonic scaling⁸². Bremerich and colleagues reported TENS to be effective in controlling chronic facial pain and reducing patients' analgesics requirements⁸³. In the treatment of symptoms associated with temporomandibular joint disk displacement without reduction, Linde et al.⁸⁴ concluded that flat occlusal splints in several respects are better than TENS. 31 patients were selected randomly to be treated 6 weeks with either TENS 90pps, 30min, three times day⁻¹ or with a flat occlusal splint, 24h day⁻¹. In the TENS group one electrode placed over the painful TMJ and another electrode over the anterior temporal muscle. The splint group used a conventional flat occlusal splint with cuspid guidance. In a single blind randomised controlled trial with 10 subjects, sub threshold TENS (35pps, pulse width 100µsec, modulation 50%) did not increase the symptom relief produced by conservative treatment of ibuprofen, bite plate and self-physiotherapy for myofascial pain dysfunction⁸⁵.

5. Electrode placement

5.1 General principles

5.2 Musculoskeletal problems

5.2.1 Dermatomes and the spine

5.2.2 Arm

5.2.3 Leg

5.2.4 Temporomandibular joint/myofacial pain

5.3 Problems specific to women

5.3.1 Dysmenorrhea

5.3.2 Premenstrual tension

5.3.3 Labour pain

5.4 Neuralgias

5.4.1 Post herpetic

5.4.2 Trigeminal

5.4.3 Postoperative

5.4.4 Peripheral

5.4.5 Phantom limb pain

5.5 Dental uses

5.5.1 Pain control

5.5.2 Temporomandibular joint/myofacial pain

5.6 Miscellany

5.6.1 Postoperative pain

5.6.2 Emesis

5.6.3 Skin ulcers

5.6.4 Irritable bowel syndrome

5.7 Care of electrodes

5.1 General principles

Generally speaking, best results are obtained by placing the electrodes directly over or surrounding the painful sites whenever possible as shown in this section. Treating appropriate acupuncture points can also be most effective but this needs specialised training which we hope to produce as part of our next CD on Needleless Acupuncture.

Electrode placement within an appropriate dermatome is usually seen as the conventional approach to TENS. It is often very useful, but it is not the only effective approach to treatment. We include four of our own colour coded dermatome charts for your reference, to help you determine appropriate electrode placements, if you wish to follow the dermatome method of electrode placement. They are the cervical, dorsal/thoracic, lumbar and sacral dermatome charts. The **dermatome charts** are followed by a comprehensive selection of treatment charts, using a combination of the methods as outlined above and are the ones we use in our daily clinical practice.

The most important positions for electrode placement for localised pain suggested by the TENS literature are **shown here** in order of priority:

- 1st.** over the painful area and diametrically opposite the pain if possible
- 2nd.** over the painful area and over the nerve root in the same dermatome or either side of the pain
- 3rd.** proximal and distal to the pain
- 4th.** crisscross pattern over the painful area
- 5th.** both electrode proximal to the painful area
- 6th.** both electrodes distal to the painful area.

The most important principles concerning electrode placement is to position them so that the current passes:

- through the painful area
- along the nerves leading from the pain within the correct dermatome

- or on acupuncture points.

If your TENS is a dual channel unit, with two sets of leads and electrode's then it is possible to treat more than one area of the pain at a time or to treat two different areas of pain at the same time.

5.2 Musculoskeletal problems

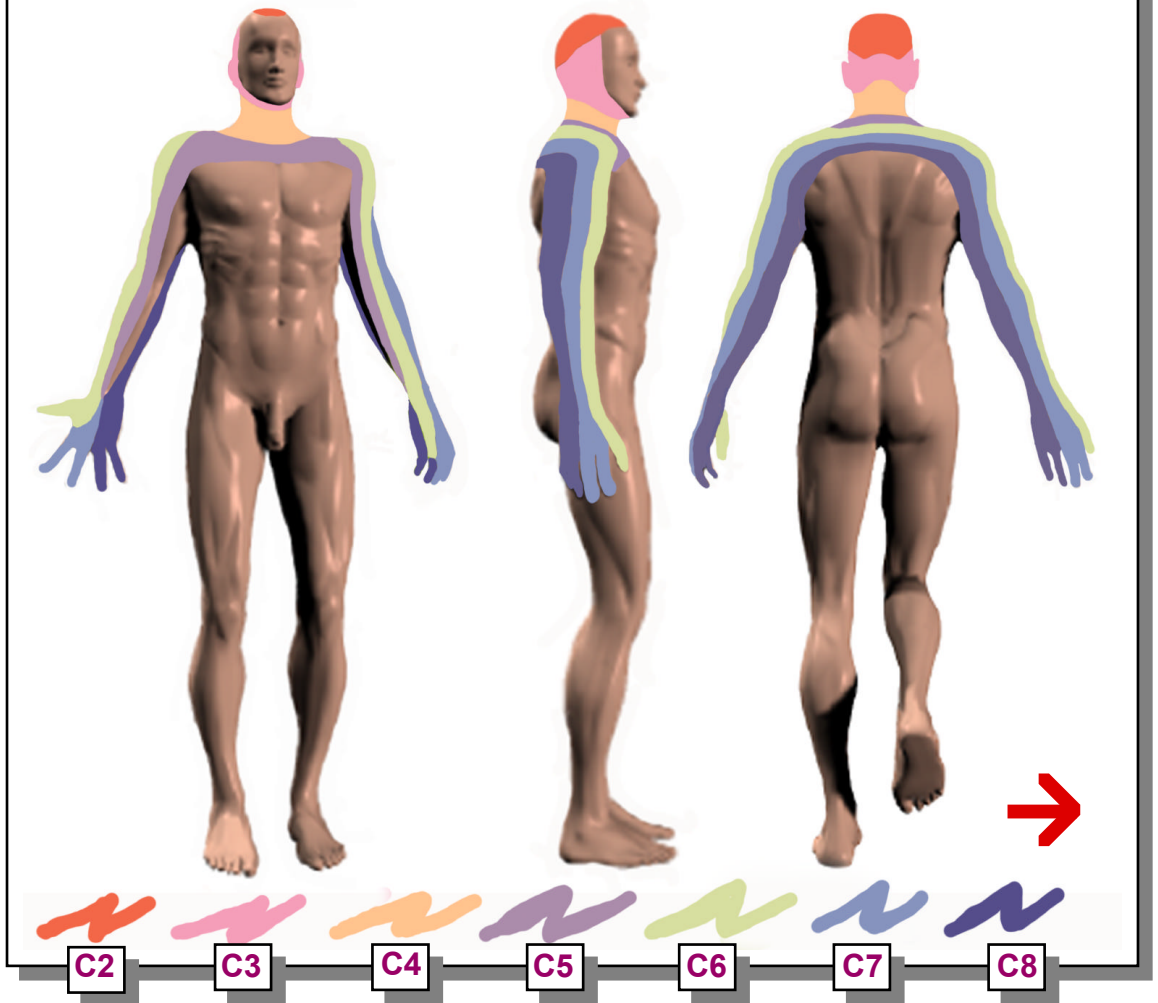
5.2.1 Dermatomes and the spine

5.2.2 Arm

5.2.3 Leg

5.2.4 Temporomandibular joint

Cervical dermatomes



Dorsal dermatomes

5

5.2

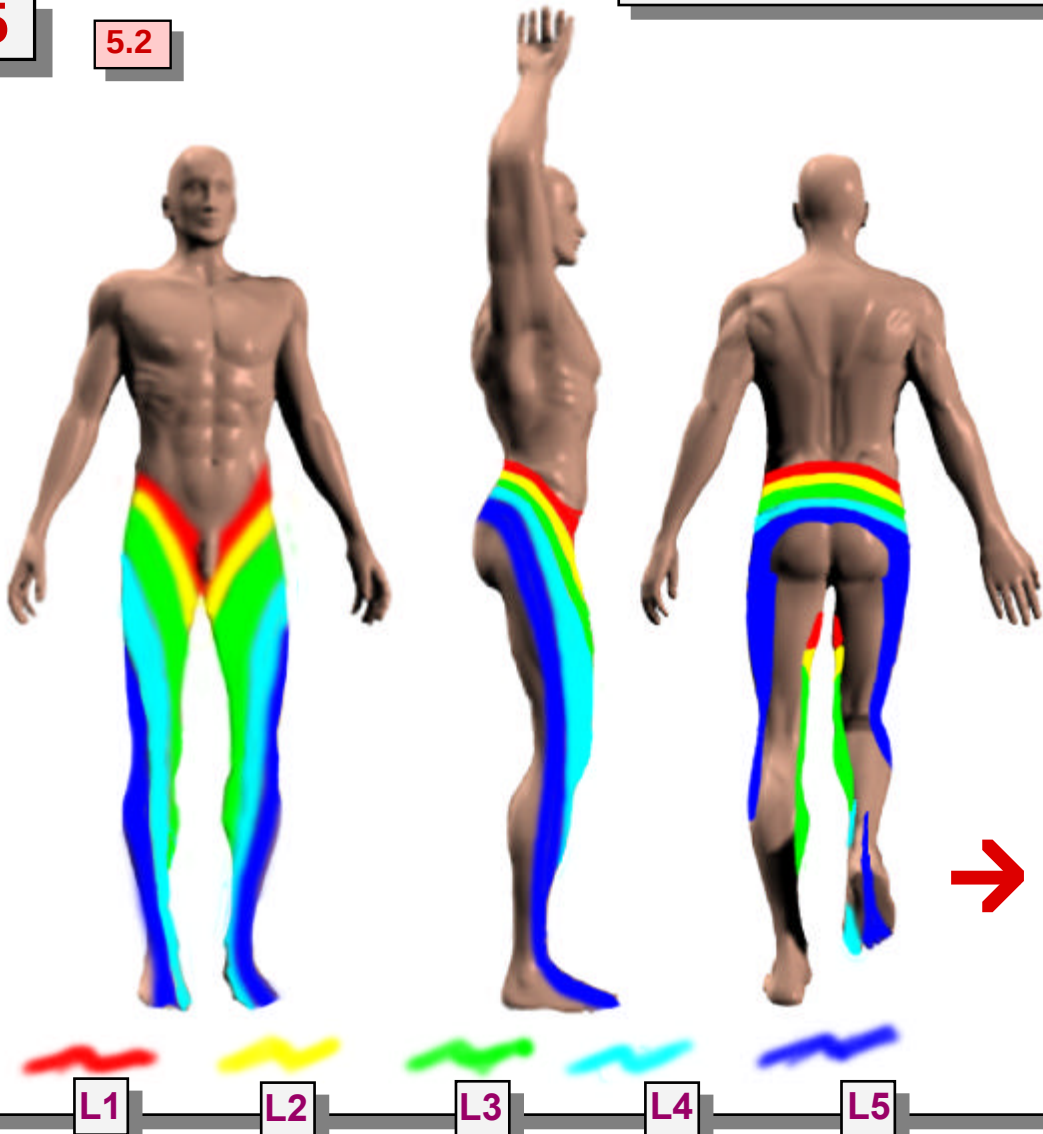


D1 to D12

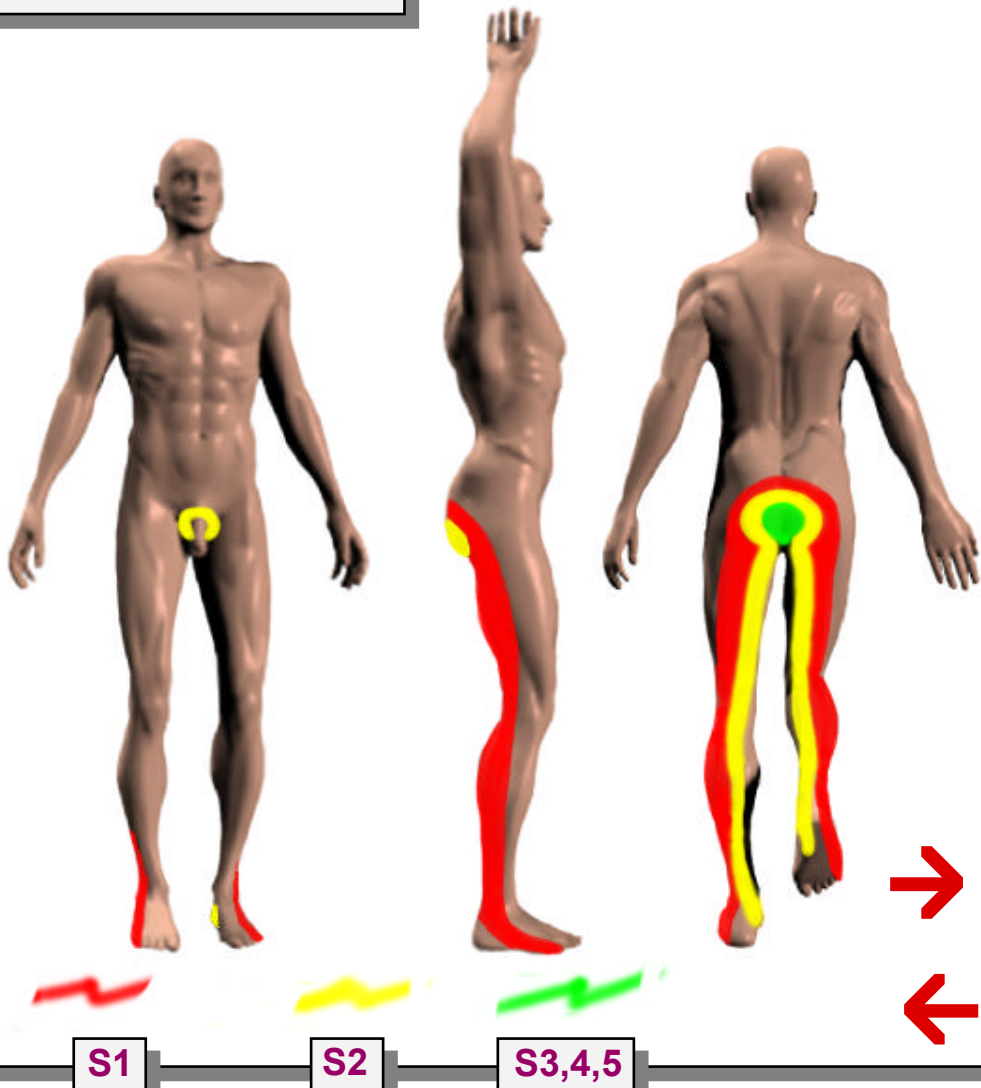
Lumbar dermatomes

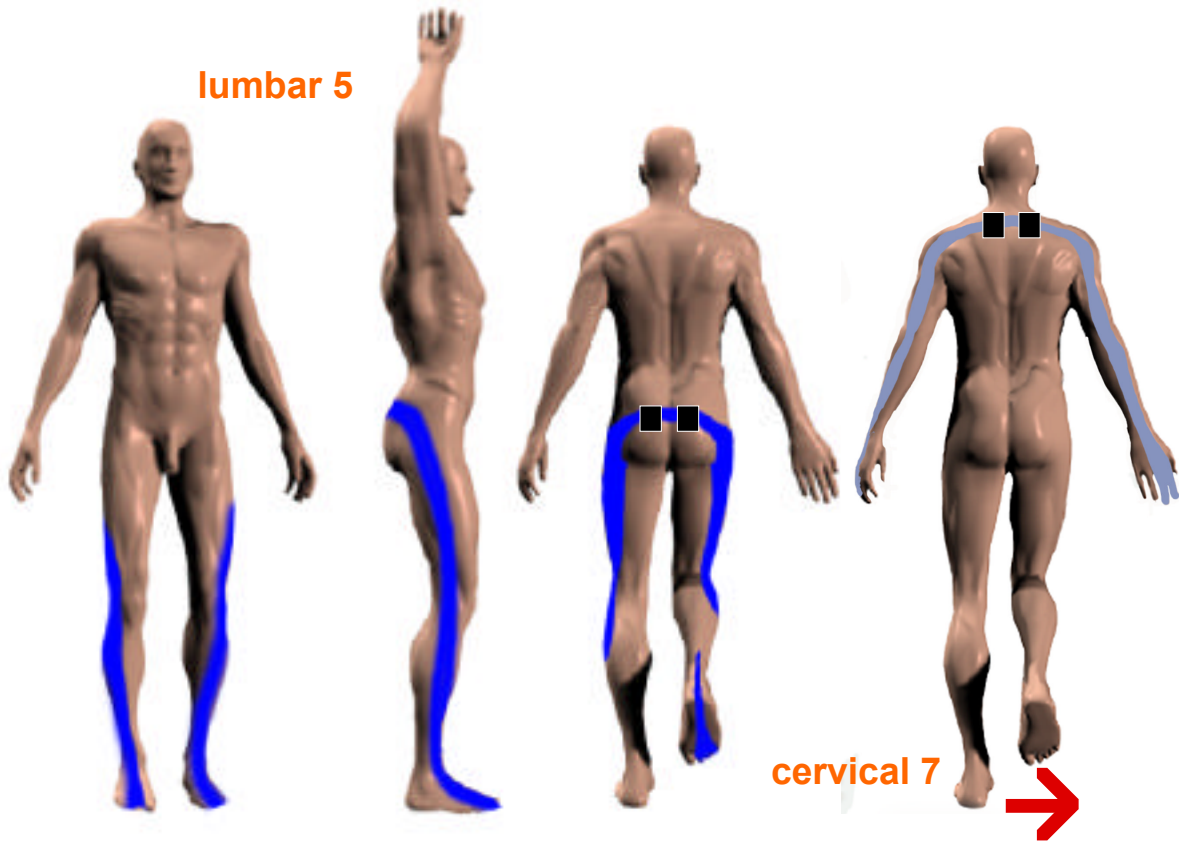
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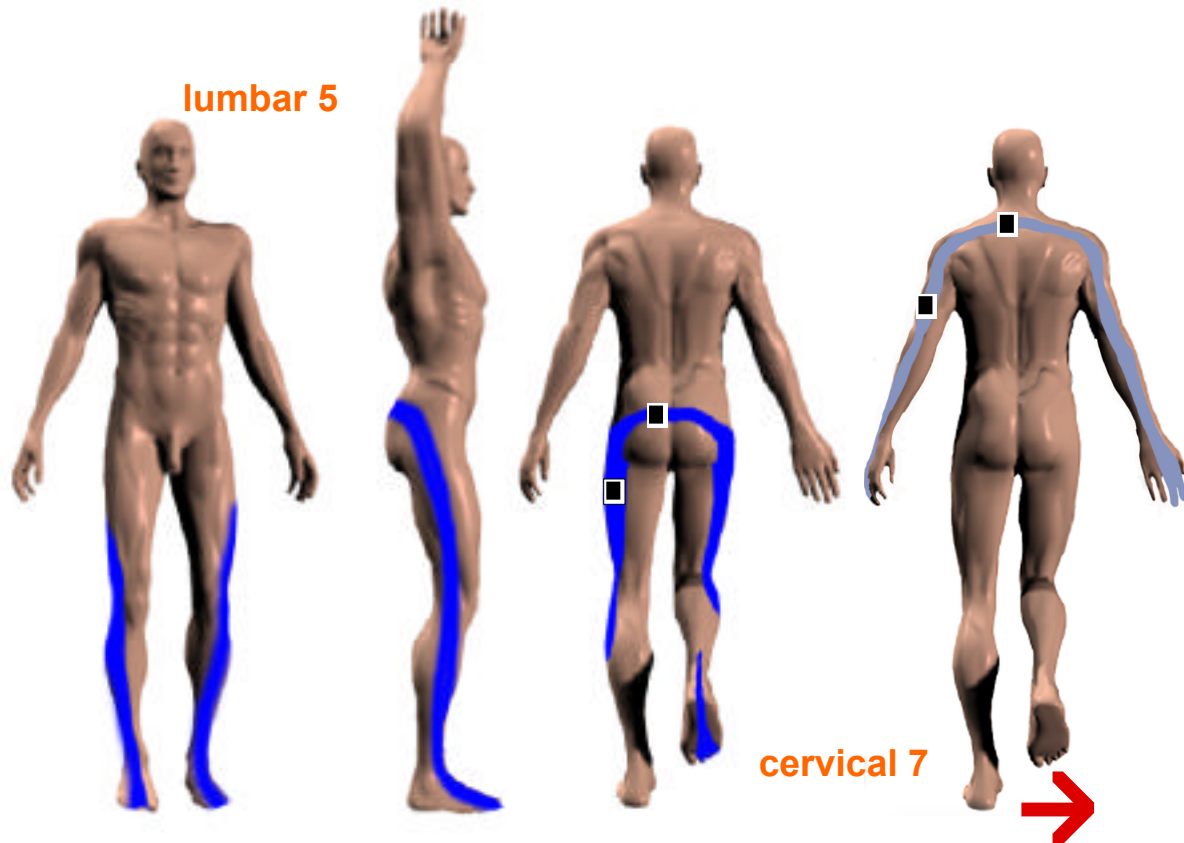


Sacral dermatomes



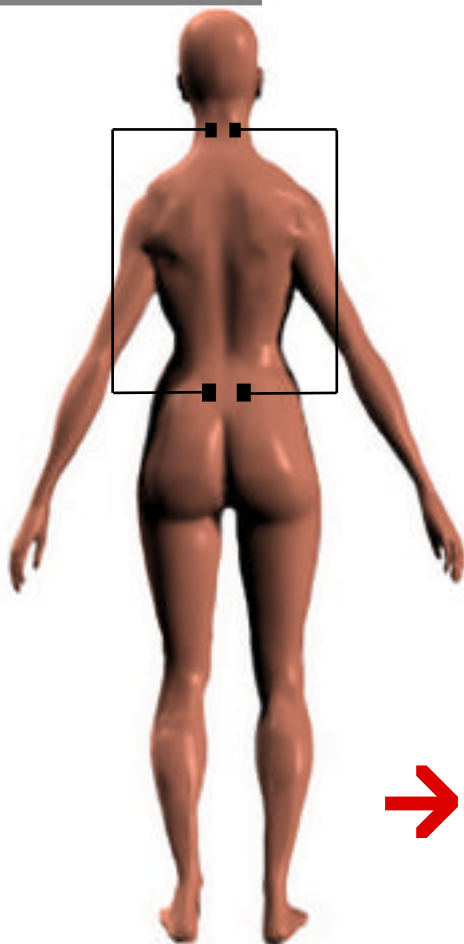


Illustrations of electrode placement for back pain and treatment within individual dermatomes. NO referred pain



Illustrations of electrode placement for back pain and treatment within individual dermatomes. WITH referred pain

Ankylosing spondylitis



5

Unilateral treatment carried out bilaterally, in this case C3 to L5.

5.2

One pair of electrodes within the dermatome of area of acute pain.

Cervical pain / whiplash injury



5

5.2

Bilateral treatment using one or more pairs of electrodes

5.2.2 Arm

5.2.2.1 Hand

5.2.2.2 Wrist

5.2.2.3 Golfers' elbow

5.2.2.4 Tennis elbow

5.2.2.5 Shoulder

5

5.2

5.2.2

**Electrode placement
hand pain**



**electrodes placed
medially and laterally
or one
over pain and other
in same
dermatome**

5

5.2

5.2.2

**Electrode placement
wrist pain**

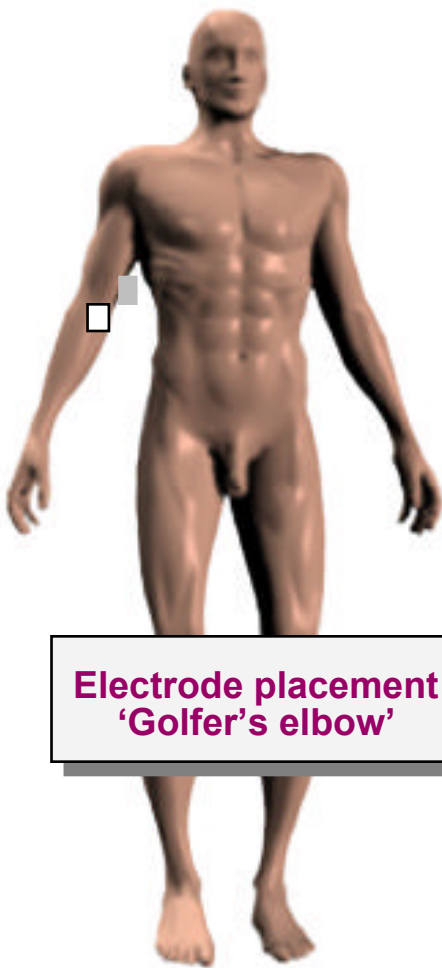


**electrodes placed
medially and laterally
or one
over pain and other
in same
dermatome**

5

5.2

5.2.2



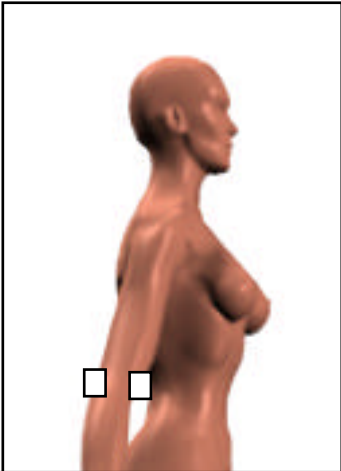
**Electrode placement
'Golfer's elbow'**

**electrodes placed medially
and laterally over epicondyle**

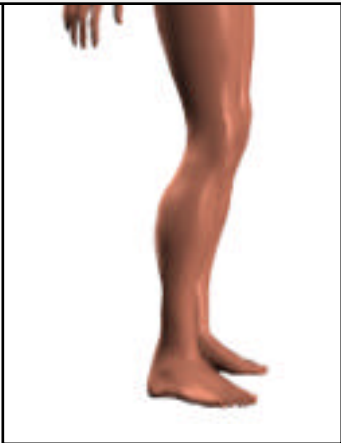
5

5.2

5.2.2



**Electrode placement
'tennis elbow'**

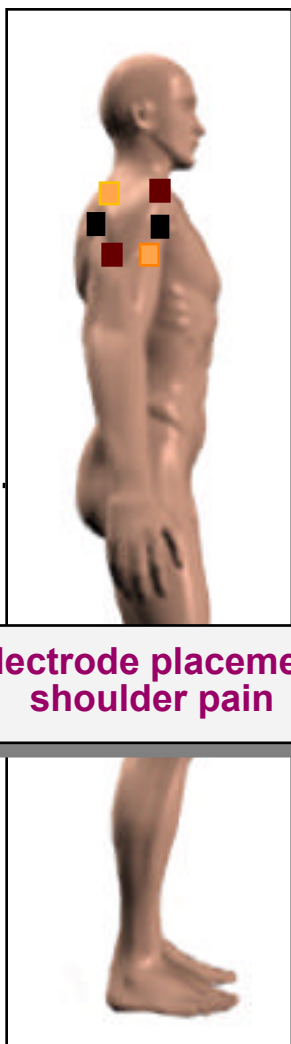


**electrodes placed
medially and laterally
over epicondyle
or
over pain and within
dermatome**

5

5.2

5.2.2



**Electrode placement
shoulder pain**

**pairs of electrodes
arranged as appropriate
to drive the stimulation
through the muscle bulk
where the pain lies**

5.2.3 Leg

5.2.3.1 Ankle

5.2.3.2 Achilles tendon

5.2.3.3 Knee

5.2.3.4 Hip

5

5.2

5.2.3

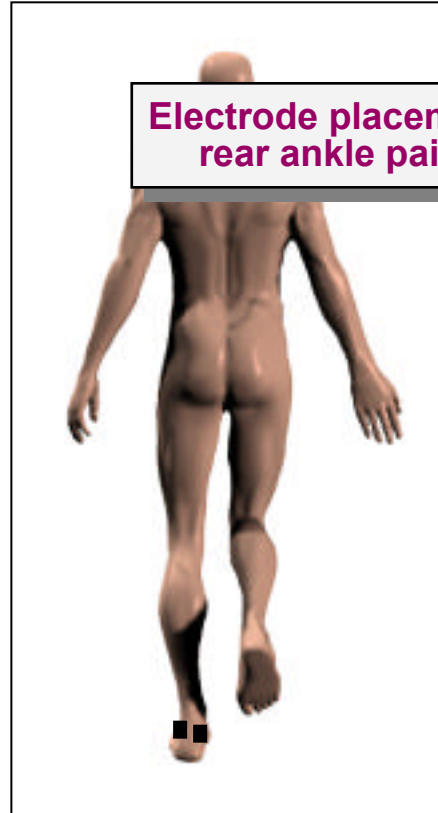
Electrode placement
ankle pain



electrodes placed medially/ laterally
or
dorsally/ ventrally



Electrode placement
lateral / medial ankle



Electrode placement
rear ankle pain

5

5.2

5.2.3

**Electrode placement
Achilles tendon**



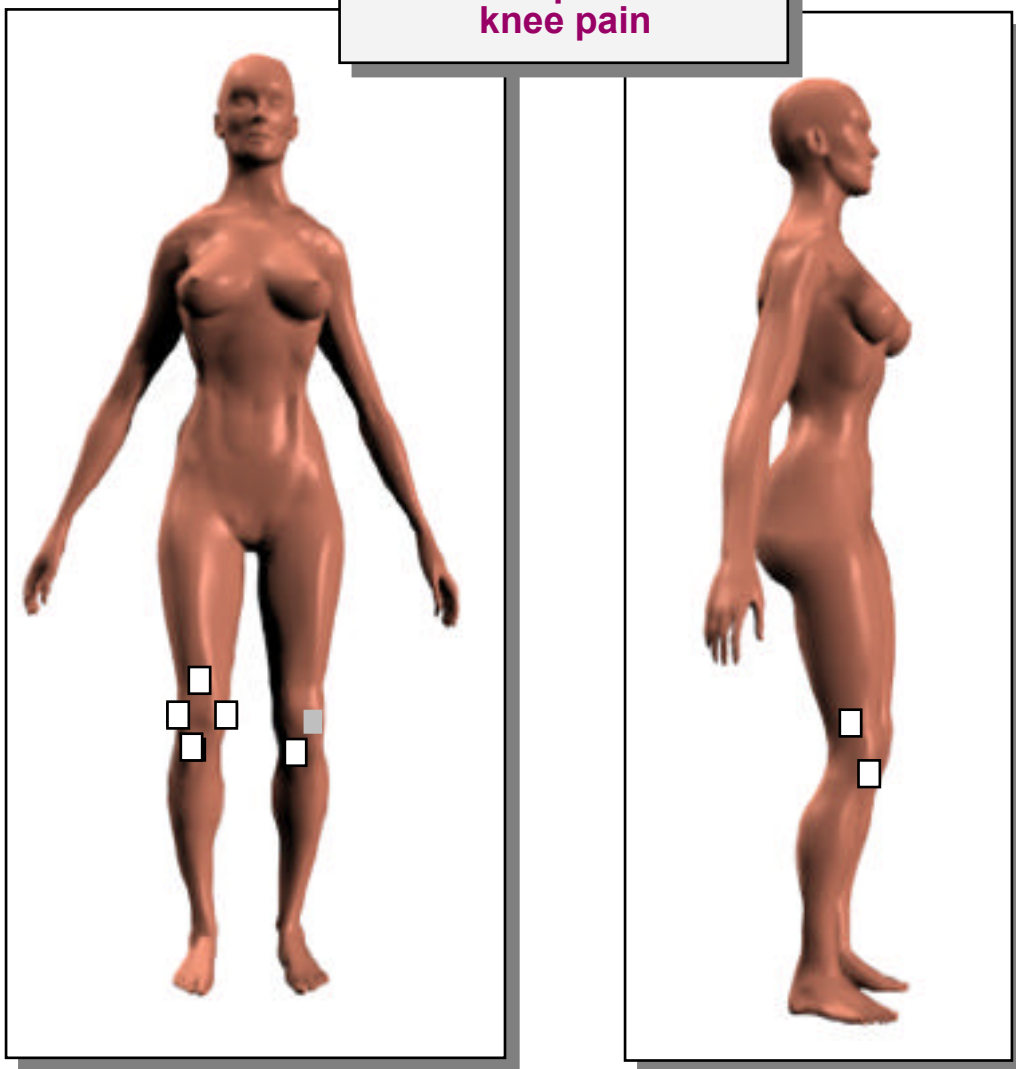
**Electrode placement over most
painful areas on both medial
and lateral aspects**

5

5.2

5.2.3

Electrode placements knee pain



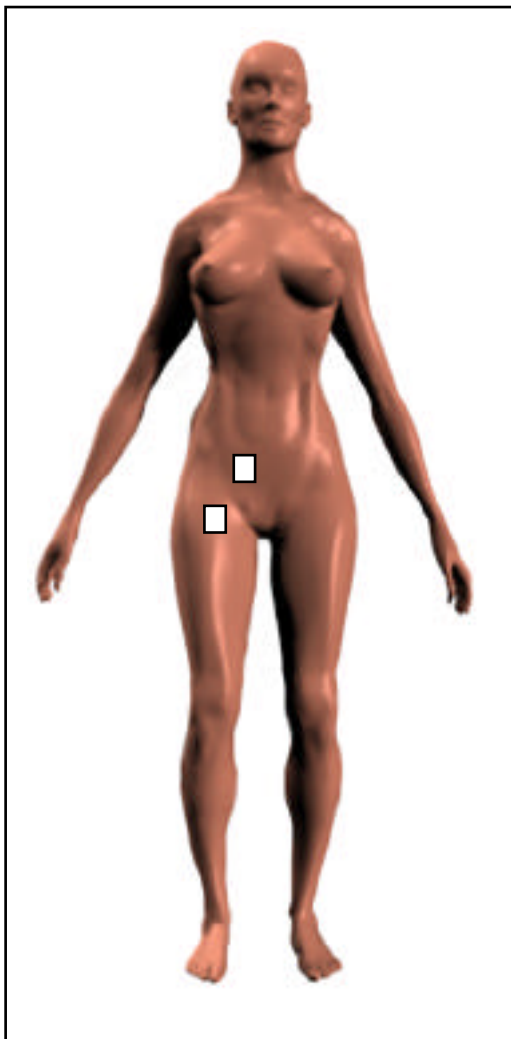
electrodes used in pairs,
one over site of pain,
the other in diametrically
opposite position

5

5.2

5.2.3

Electrode placements hip pain



5.2.4 Temporomandibular joint/ myofacial pain

either

or

**Electrode placements
for temporomandibular
joint and myofascial pains**

5.3 Problems specific to women

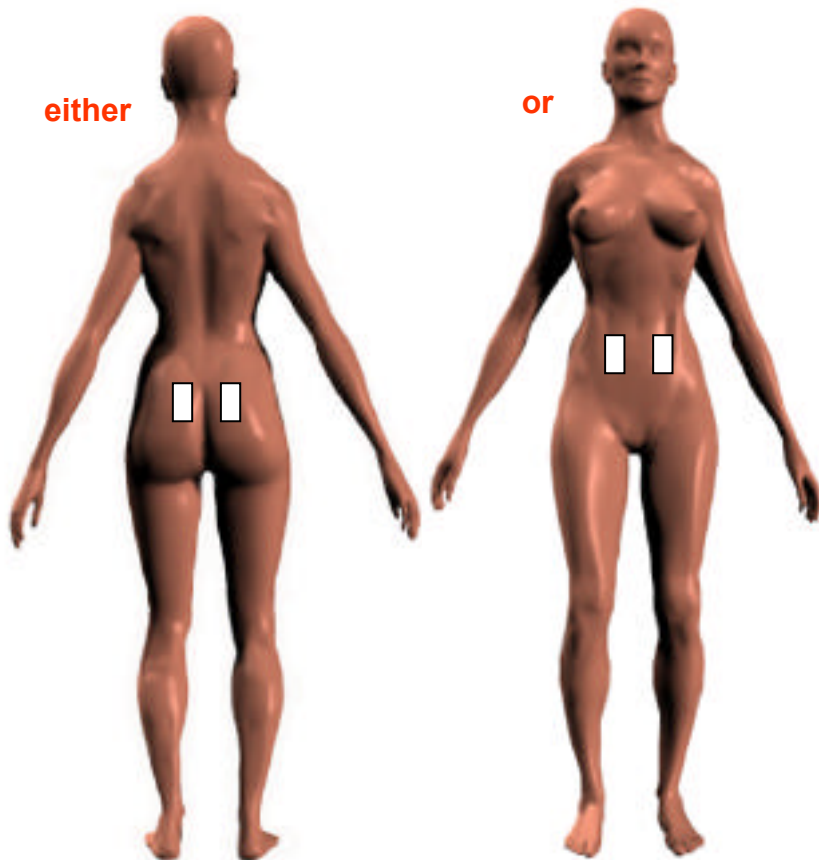
5.3.1 Dysmenorrhea

5.3.2 Premenstrual tension

5.3.3 Labour pain

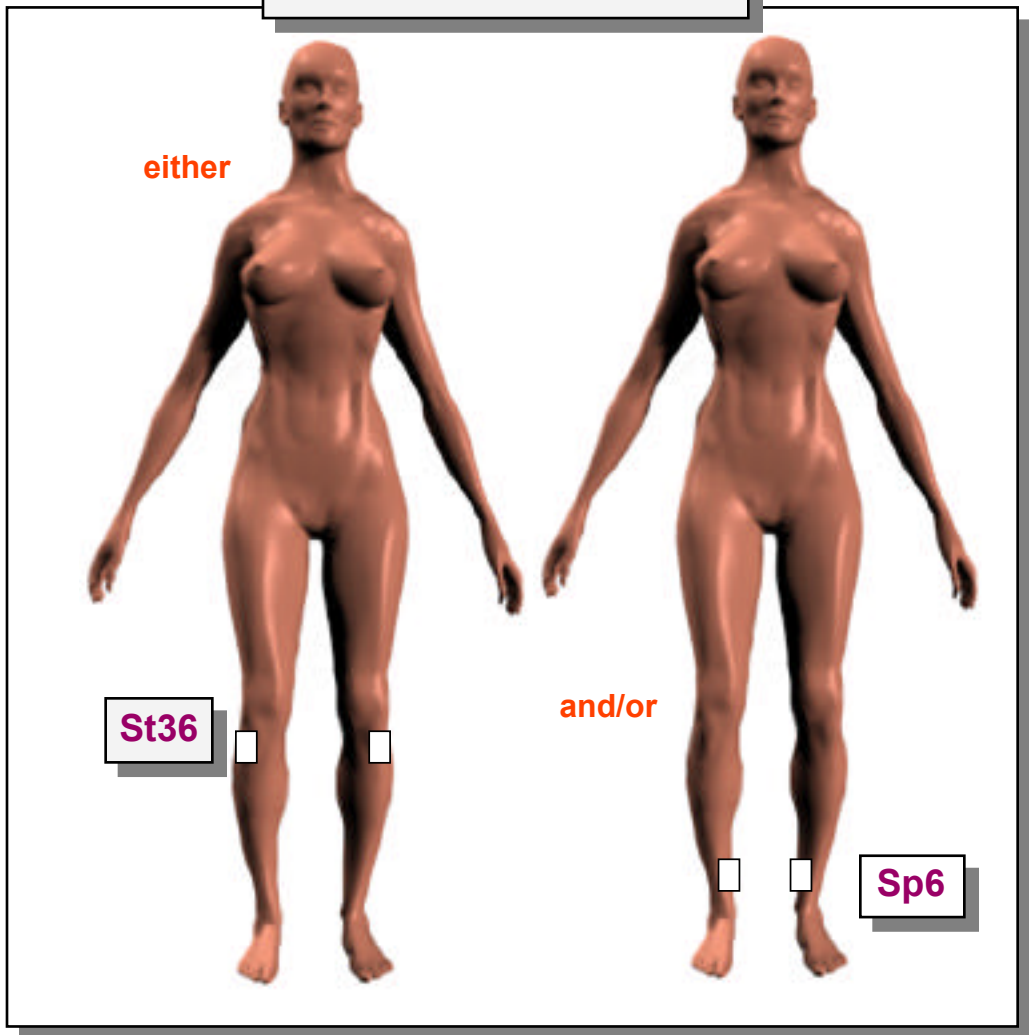
either

or



Electrode placements
for primary
dysmenorrhea

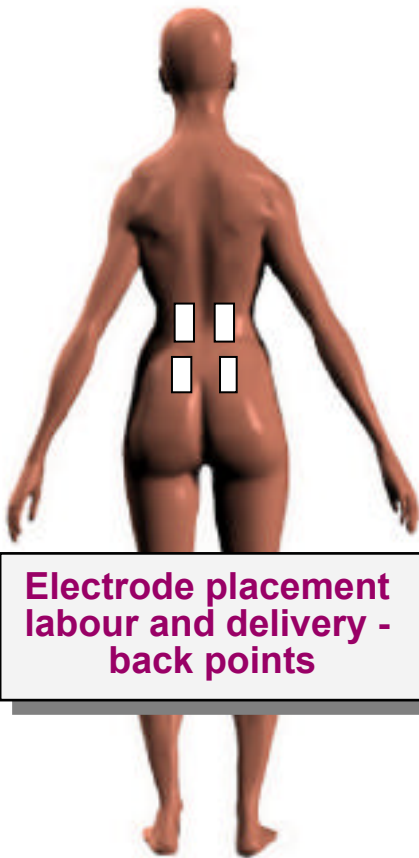
Electrode placements for premenstrual tension



based on two acupuncture points:

St36 is located between the heads of the tibia and fibia
3 fingers below the lower border of the patella

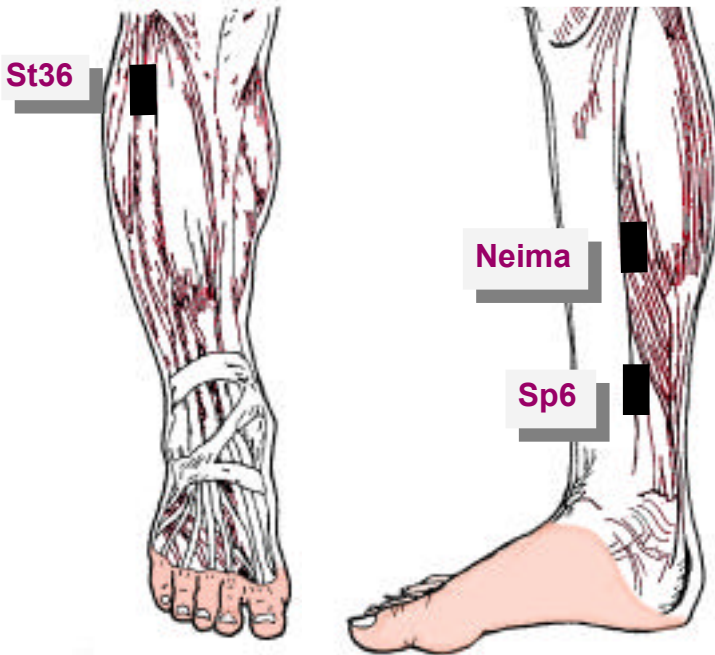
Sp6 is on the posterior edge of the tibia, three finger breadths
proximal to the highest point on the medial malleollus;



**Electrode placement
labour and delivery -
back points**



Electrode placement for labour and delivery - leg points



**St36 is located between the heads of the tibia and fibula
3 fingers below the lower border of the patella**

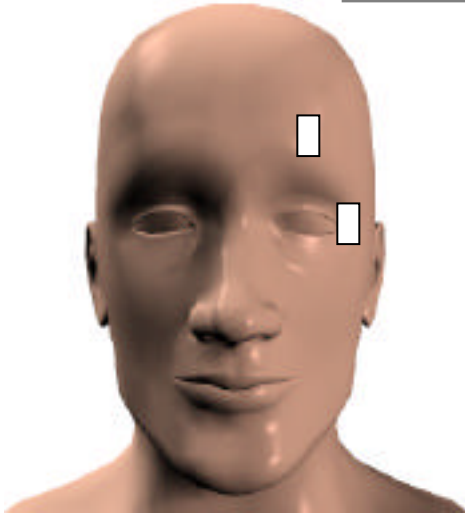
**Sp6 is on the posterior edge of the tibia, three finger breadths
proximal to the highest point on the medial malleolus**

**Neima is located one hand width below the medial
epicondylar ridge of the tibia**

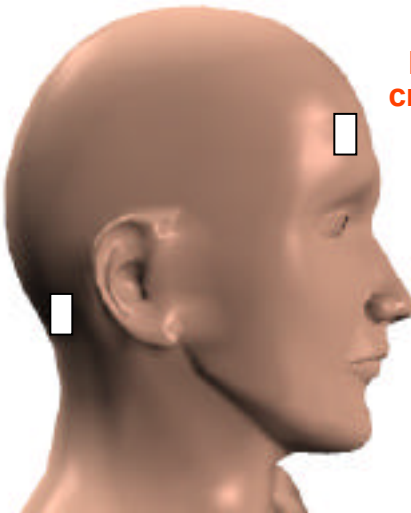
5.4 Neuralgias

- 5.4.1 Post herpetic**
- 5.4.2 Trigeminal**
- 5.4.3 Postoperative**
- 5.4.4 Peripheral**
- 5.4.5 Phantom limb pain**

Electrode placement for post herpetic neuralgia on the torso or head

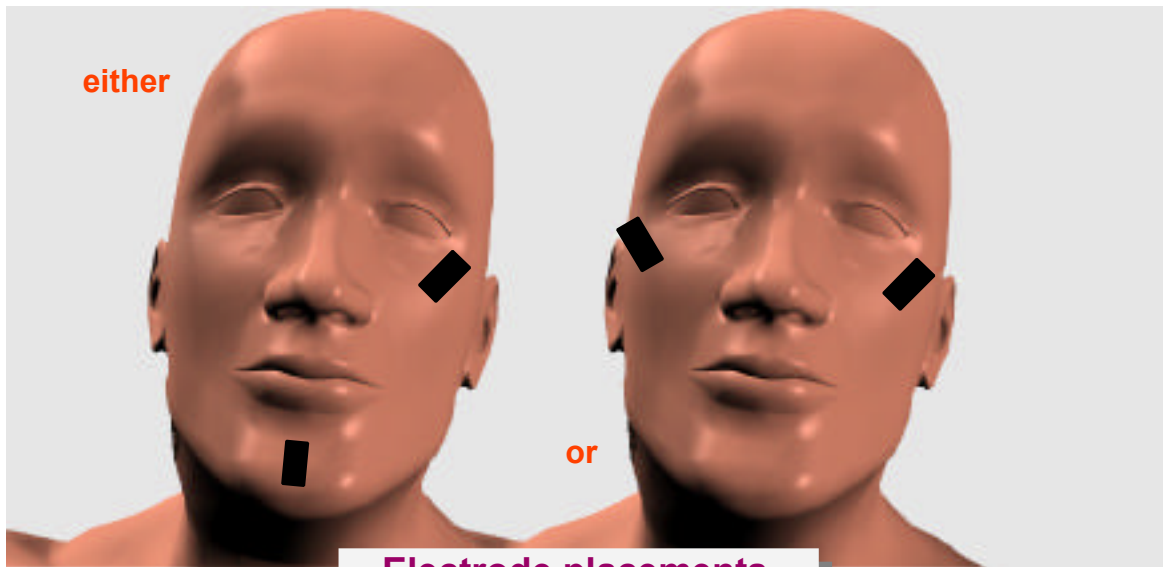


either or
depending on location
and gentle stimulation



on the torso
pairs of electrodes
bridging painful area,
criss-cross if necessary





**Electrode placements
for trigeminal neuralgia
and myofascial pains**

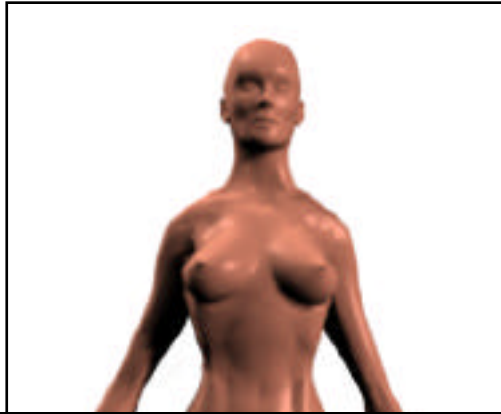
**Electrode placement for
postoperative neuralgia
over site of pain and
diametrically opposite**

5

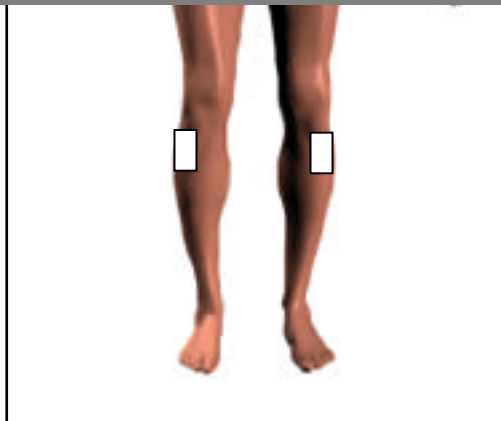
5.4



**not to be used
on the thorax**

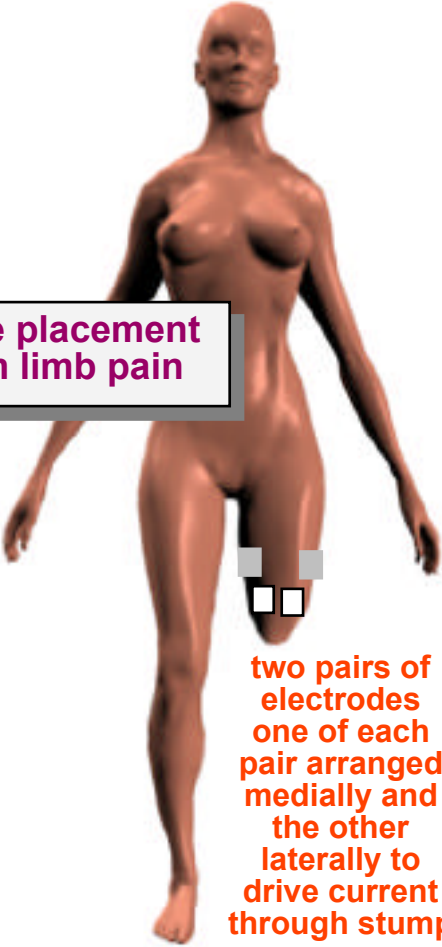


Electrode placement peripheral neuropathy - pair of electrodes at site of pain plus pair on acupuncture point St36



**St36 is located between the heads of the tibia and fibia
3 fingers below below the lower border of the patella**

Electrode placement phantom limb pain



two pairs of
electrodes
one of each
pair arranged
medially and
the other
laterally to
drive current
through stump

5

5.5 Dental uses

5.5.1 Pain control

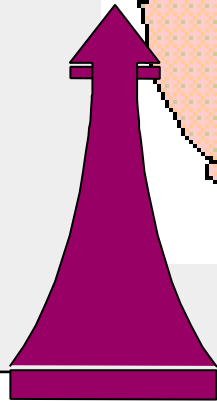
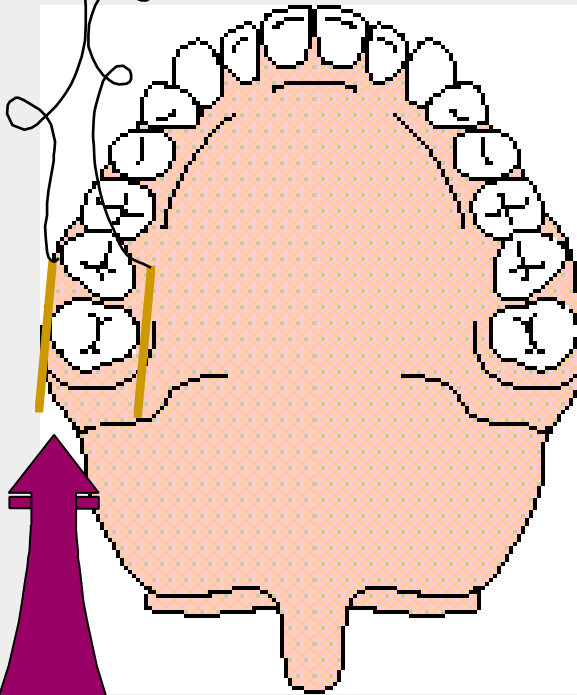
5.5.2 Temporomandibular joint

5

5.5

TENS

Electrode placement
to anaesthetise teeth

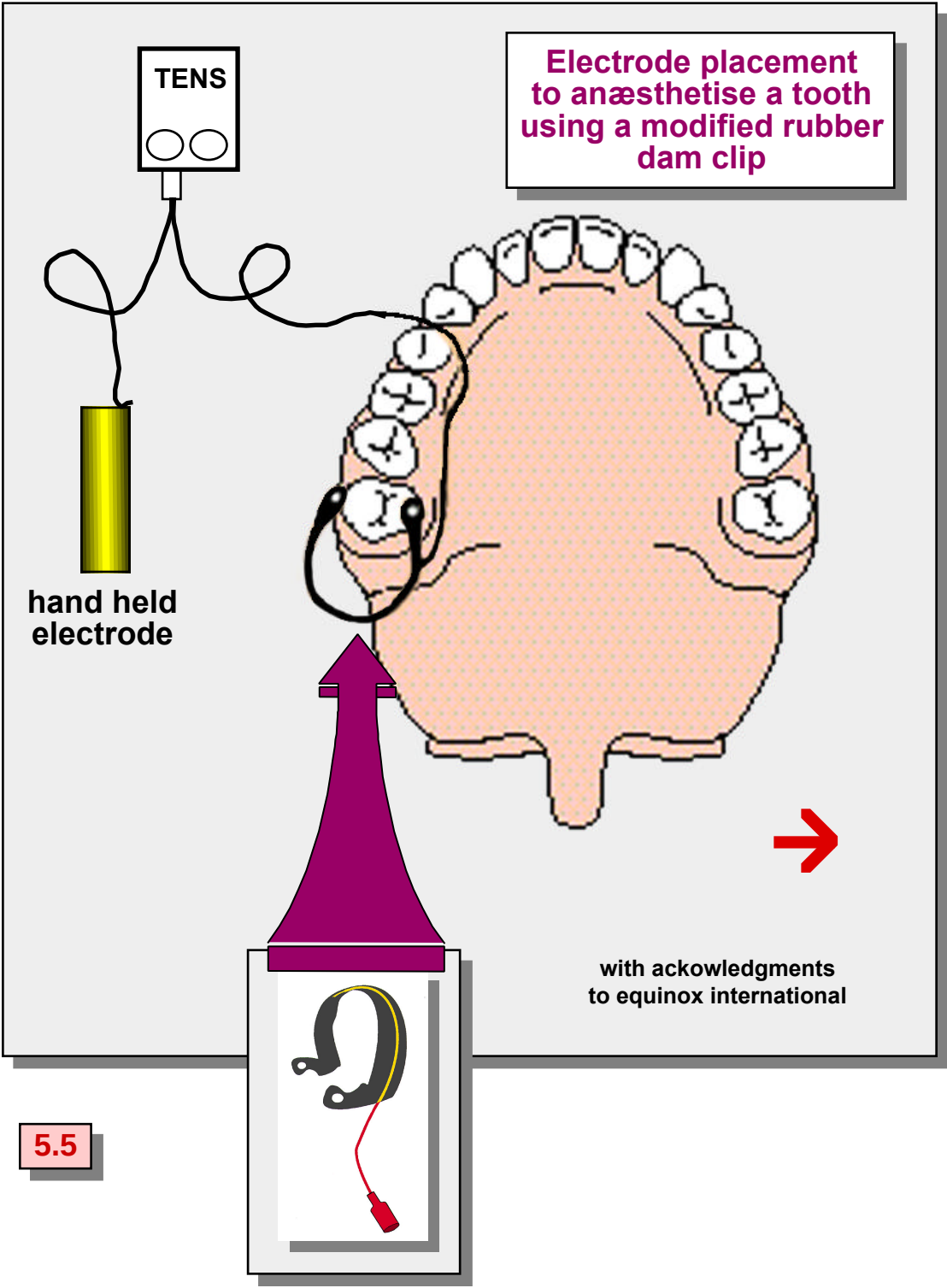


Adhesive electrode

adhesive



conductive pad

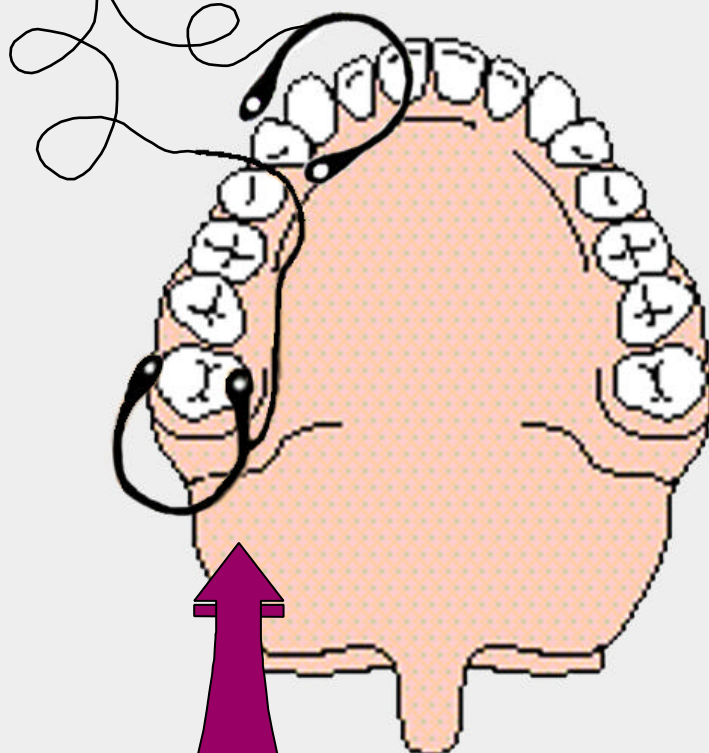


TENS

Electrode placement
to anaesthetise teeth
using 2 modified rubber
dam clips

5

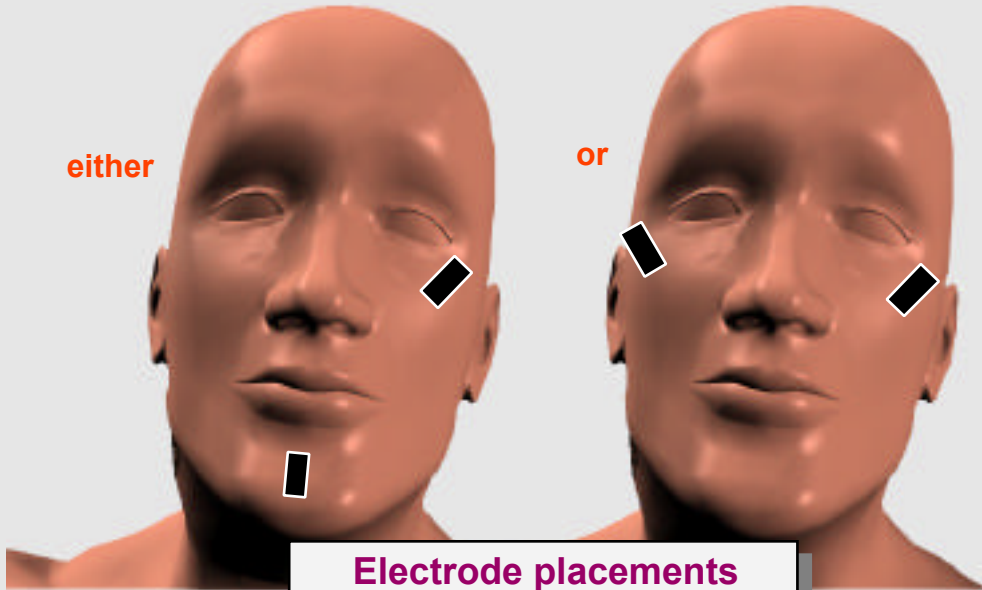
5.5



with acknowledgments
to equinox international

either

or



**Electrode placements
for temporomandibular
joint and myofascial pains**

5

5.5

5.6 Miscellany

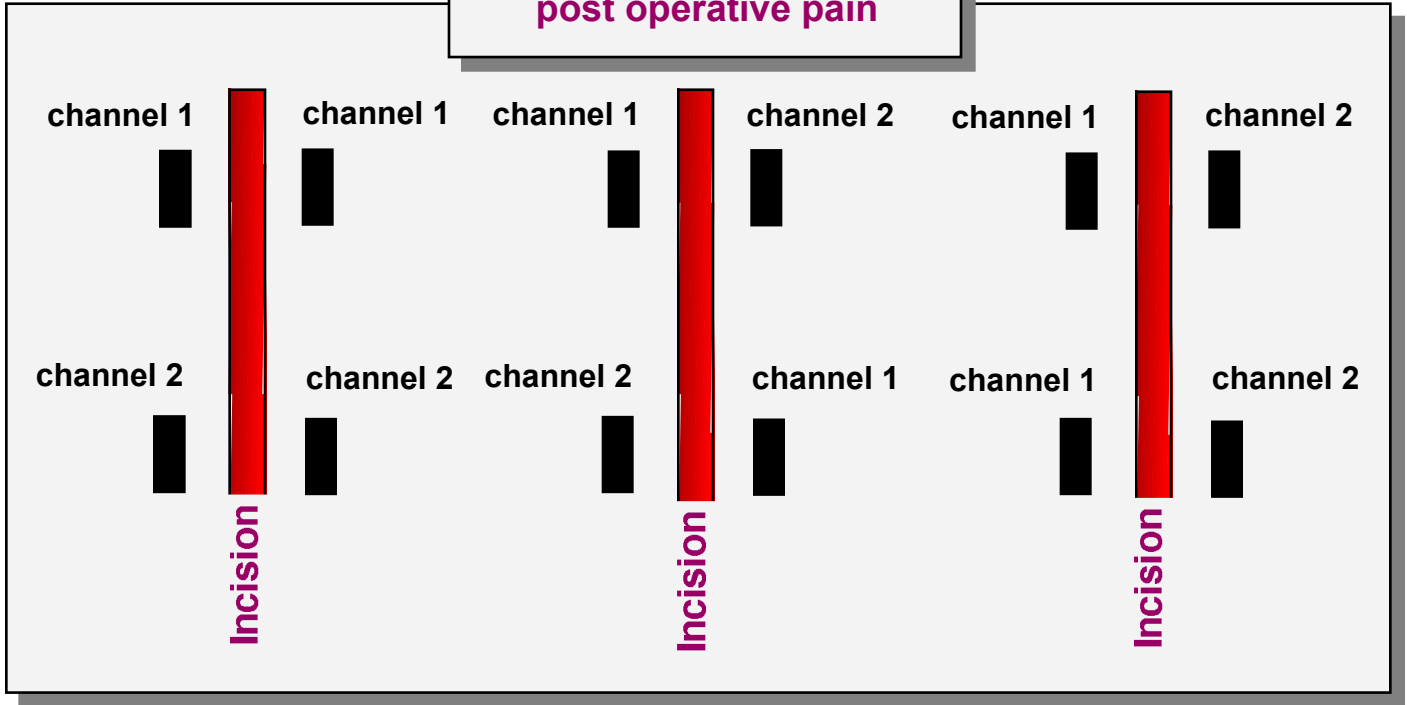
5.6.1 Postoperative pain

5.6.2 Emesis

5.6.3 Skin ulcers

5.6.4 Irritable bowel syndrome

Various combinations of
electrode placement for
post operative pain



5

5.6

Electrode placement
for
nausea and vomiting

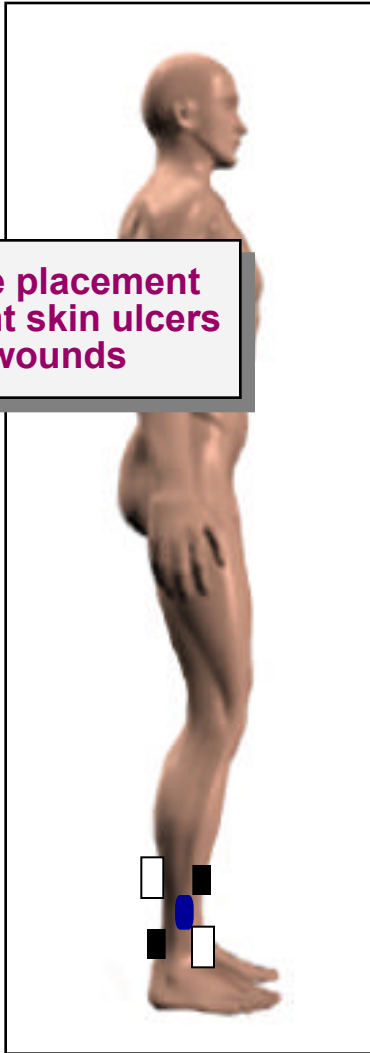
P6

P6 is located 3 finger breadths above the proximal crease of the wrist at the lateral edge of the tendon of the palmaris longus muscle

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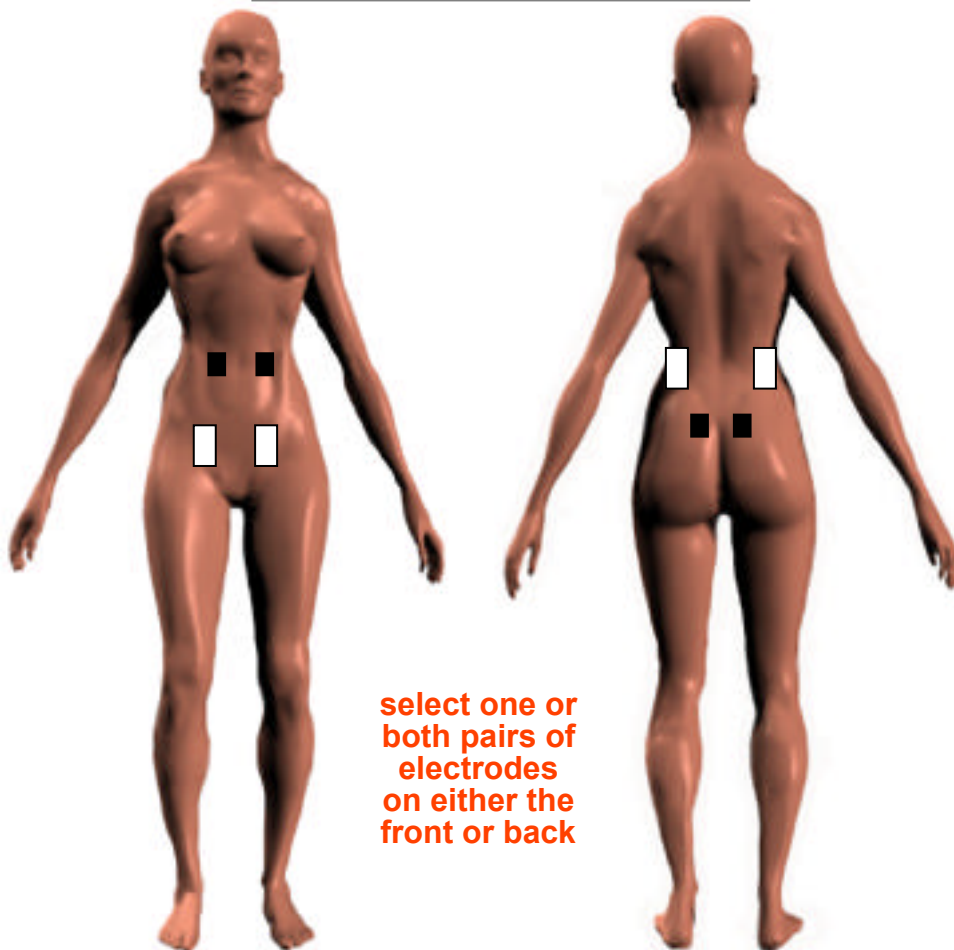
5.6

**Electrode placement
recalcitrant skin ulcers
and wounds**



**apply electrodes diagonally to healthy skin
in criss cross pattern**

Electrode placement irritable bowel syndrome



select one or
both pairs of
electrodes
on either the
front or back

5

5.7 Care of electrodes

5.7 Care of electrodes

Electrodes should be inspected regularly. It is necessary to replace self adhesive electrodes when they no longer stick to the skin consistently. The usual life span is approximately 6 to 8 weeks, depending on how often they are used and how well they are looked after; these electrodes will last longer if the skin is carefully wash prior to use and they are returned to their storage backing plastic after use. Self adhesive electrodes are considered to be hypo allergenic, however, occasionally some clients with ultra sensitive skin may develop an allergy to this type of electrode. The solution is to change to another type of electrode such as the carbon rubber ones.

Carbon rubber electrodes may last longer than self adhesive ones but do need replacing when they become worn looking or the pin on the leads tend to fall out of the electrode socket. Carbon rubber electrodes should be wiped clean/washed to remove excess conductive gel after each treatment. Self adhesive electrodes should be stored in a cool dry place and returned to their storage bag between use, following the instructions supplied to maintain adherence.

Varying the electrode placements slightly or changing to a different type of electrode can usually control any minor skin reactions to the electrodes.

It is not usually recommended to use TENS during night sleep; agitation during the night could dislodge or damage electrodes or excessive pressure on the electrodes may result in increased skin irritation. However, TENS treatment may be used with good effect for 30 to 60 minutes before going to bed.

If you feel that the TENS unit is not working correctly you should inspect each of the electrode pads for adequate adhesion or contact gel. Make sure the TENS lead wires are firmly in place in the TENS unit and attached to the electrodes,. The most common problem leading to ineffective operation of TENS units is insufficient charge in the battery so check that

5

5.7

batteries are fully charged.

However, all accessories will eventually wear out and simply replacing them can solve most problems.

6. Precautions to be taken with TENS



6. Precautions to be taken with TENS

An advantage of TENS is that it can be combined with most other therapies - conventional medication, physiotherapy, acupuncture, exercise, massage, herbal medicine, homeopathy, chiropractic and osteopathic manipulation, hot and cold packs. However, if your patient is receiving more than one treatment at a time, it may be difficult to know which is effective; try not to use more than two treatments simultaneously so that you can assess response more accurately.

This review of precautions to be taken with TENS is based on the recommendations and suggestions of [number of authors^{1,2,3}](#).

TENS should not be used where the cause of the pain has not been properly diagnosed and if your patient has a demand type cardiac pacemaker, a serious/unstable heart condition or has had a recent heart attack.

Caution should be applied if your patient is pregnant or if they have tuberculosis, malignant tumours, high or low blood pressure, epilepsy, high fever or acute inflammatory disease. Normally, electrodes should be applied only to skin with normal sensation.

As a precaution, patients are often advised not to use TENS if driving, operating potentially dangerous machinery or using a microwave oven. However, we have found no evidence to substantiate such caution.

Do NOT place electrodes on or near the eyes, in the mouth (unless specifically designed for dental procedures), over the front or sides of the neck, across the head, across the heart, over the genitals, over an area of broken, inflamed or infected or numb skin.

Trim any excess body hair, which could interfere with smooth electrode contact with the skin with scissors but do not shave it.

As with most forms of treatment, complications can arise but these are infrequent:

- allergic skin reactions may occur to either the electrodes, the gel or the fixing tape. Usually this can be remedied by replacing the electrodes, gel or tape with an alternative product
- when conductive gel is used with carbon electrodes, skin irritation may occasionally occur due to drying out of the gel under the electrode; care should be taken not to let the electrode gel dry out.

Washing and drying the electrode application skin site before treatment, can reduce the incidence of skin irritation under the electrodes. Firm electrode contact with the skin over the entire electrode surface is very important for effective treatment. If the electrode is not secure, has inadequate adhesion or too little gel then intermittent stimulation may occur, which might be uncomfortable and could result in skin irritation.

If skin irritation still occurs, despite the above guidelines then discontinue use, advise on remedial action and try again once the skin has healed.

Moisturising skin cream may be applied after treatment.

If the TENS unit fails to work:

- check the battery is fitted into the battery compartment correctly
- check that the battery is connected correctly to the TENS unit
- check that the battery is fully charged - if you are not sure replace the battery anyway and test it out again
- check that the leads and electrodes are firmly connected to the unit and correctly applied.

If only one channel appears to be working then try each set of leads in each channel to determine which, if any, of the leads may not be working. If a set of leads is found to be faulty then replace them with a new set.

TENS units require no maintenance other than regular and gentle cleaning of the case, connecting leads and carbon rubber electrodes. Using a soft cloth, slightly moistened with warm water, wipe clean the case, connecting leads and electrodes. A mild soap may also be used but **do not** apply solvents. Should the inside of the TENS unit become wet, allow it to dry thoroughly before using it again but do not place it near a strong source of heat. If the unit is dropped or subjected to excessive moisture or otherwise damaged, do not use it but contact your supplier for advice.

- Do not immerse this TENS unit in water or any other liquid
- do not place it close to any source of excessive heat
- do not operate this unit in the presence of flammable gases
- do not attempt to open up the TENS unit
- do not use any other battery or power source but the ones specified
- do not drop this unit on to a hard surface.

7. Developments, electricity and acupuncture



7. Developments, electricity and acupuncture

The use of transcutaneous electrical nerve stimulation has undergone an extensive growth over the last 25 years. TENS treatments can be divided into two basic types - conventional, high frequency, low intensity TENS and acupuncture-like transcutaneous electrical nerve stimulation (ALTENS) using the electrical stimulation parameters often used for electroacupuncture. In ALTENS the stimulation used is at low frequency but at high intensity. Conventional TENS uses a high pulse rate, narrow pulse and moderate stimulation with parameter adjustments for rate between 50 to 200pps, a low pulse width of around 80 µsecs and an intensity raised to the level of comfort. Acupuncture-like TENS, also known as strong low rate (SLR) TENS, has electrical parameters adjusted to provide a low rate (1 to 4pps), a wide pulse width between 150 to 250 µsecs and an intensity at as high a level as tolerated by the patient^{1,2}. We have produced a meta-analysis investigating published papers to try and establish the relative efficacy of these two broad approaches for the treatment of chronic low back pain as part of the Cochrane Collaboration³. The next obvious step is to apply electrical stimulation to acupuncture points but via surface electrodes as opposed to needles. This section is a short introduction to the more recent developments in acupuncture without using needles.

As you have seen in some of the previous sections, we have occasionally introduced treatment at some acupuncture points. There is an increasing interest amongst acupuncture practitioners who use electrical stimulation on acupuncture points via needles (electroacupuncture) in the development in techniques not requiring the use of needles. Also, an increasing number of practitioners using TENS in their armamentarium are interested in electroacupuncture. The authors have been involved for a number of years in the development of needleless electroacupuncture, initially for the treatment of drug dependency, and more recently as home treatments which patients can do for themselves under appropriate supervision on a very regular basis, rather like an 'electrical prescription'.

As well as stimulating individual acupuncture points, it is possible to treat channels or meridians using conductive rubber electrodes and auricular points using clips or point electrodes held by the practitioner. Light from lasers or light emitting diodes can also be used on the acupuncture system.

A new term has been coined by George Ulett and Jisheng Han to describe the treatment whereby TENS electrodes are applied to acupuncture points and trigger points using suitable electrostimulation units. This Neuro-electric acupuncture (NEAP) can be used for the treatment of a wide range of conditions, as well as pain alone. Recent [articles^{4,5}](#) by George Ulett and colleagues describes a series of studies to examine the mechanisms of acupuncture for pain relief. After reviewing studies using acupuncture and electroacupuncture, they showed that electroacupuncture (EAP) via needles is more effective than manual acupuncture. What was specially of interest to us was that they concluded that electrical stimulation via skin patch electrodes was equally effective as EAP and this is the basis of the new technique they describe as Neuro-electric acupuncture. They go on to describe clinical studies indicating effectiveness for the treatment of various types of pain, depression, anxiety, spinally induced muscle spasm, stroke, gastrointestinal disorders and drug addiction. They explored, in detail, the evidence-base for traditional acupuncture, its history, mechanisms, present status, reviewing pertinent articles in the literature, including their own research and, significantly, they had access to recent important studies from China.

As we have described in Section 2, there is now considerable evidence to explain the mechanisms of electroacupuncture, classically explained by Traditional Chinese Medicine in the context of the Daoist philosophy of the 6th.century BC teacher Lao Tzu whereby "meridian theory" acupuncture used needles to remove blockages of, and otherwise manipulate and balance, a hypothetical vital, life force called 'Qi'. However, in the last three decades scientific research on acupuncture, coupled with advances in knowledge about pain control mechanisms, have yielded sufficient

information to develop acupuncture based entirely on scientific principles. Needles are not necessary. Modern approaches to electroacupuncture require no metaphysical rituals; it is relatively simple, a useful clinical tool for pain control and other conditions, can be easily taught to practitioners and used alongside conventional medicine.

We prefer to describe this technique as needleless acupuncture by using the same acronym NEAP. This approach allows the application of electrostimulation without piercing the skin to the full range of acupuncture treatments and, to a more limited extent, allows patients to treat themselves under instruction. This is a more complex subject than TENS alone and which we hope to cover in detail in our next production; we have a long history of using these techniques over the past twenty years or so. Acupuncture is one of the most popular treatments in complementary medicine. We feel that more patients would benefit if practitioners learnt modern scientific acupuncture and used it when indicated for the treatment of pain and a wide range of other conditions.

If you would like to know more about Needleless electroacupuncture (NEAP) then register your interest with us, send an e-mail to joseph.gadsby@virgin.net and we will sign you up for early notification of our next CD release.

8. References

8. References

Section 1

1. König W. Neun Jahre Irak. 1940. Rudilf M Rohrer verlag, Brunn.
2. Kellaway P. The William Osler Essay. The part played by electric fish in the early history of bioelectricity and electrotherapy. Bull Hist Med 1940;20;112-37.
3. Stillings D. Mediterranean origins of electrotherapy. J Bioelectr 1982;2(2/3);181-6.
4. Colwell HA. An Essay on the History of Electrotherapy and Diagnosis. 1922. Heinemann, London.
5. Heilborn JL. Electricity in the 17th and 18th Centuries. 1979. Berkley Press, University of California, 606pp.
6. Gadsby JG. Rev. John Wesley MA: Holistic Healing, Electrotherapy and Complementary Medicine. 1996, Teamprint, Leicester, 56pp.
7. Cavallo T. A Complete Treatise on Electricity in Theory and Practice with Original Experiments Containing the Practice of Medical Electricity Besides other Additions and Alterations. I & II. 1796. C Dilly, 3rd edition.
8. Licht S. History of Electrotherapy. In: Therapeutic Electricity and Ultraviolet Irradiation. Ed. Licht S. Physical Medicine Library 1959;4,1. Elizabeth Licht, New Haven, USA, pp1-9.
9. Geddes LA Hoff HE. The discovery of bioelectricity and current electricity (the Galvani-Volta controversy). IEEE Spectrum 1971;8(12); 38-46.
10. La Beaume M. On Galvanism. 1826. F Ware, London, 271pp.
11. Churchill JM. A Treatise on Acupuncture: With Directions for its Performance and Cases Illustrating Its Success. 1821. Simpkin and Marshall, London.
12. Berlioz LVJ. Mémoires sur Les Maladies Chronique, Les Evacuations Sanguines et L'Acupuncture. 1816. Croullebois, Paris.
13. Sarlandière JB. Mémoires sur l'Electro-puncture. 1825. Delaunay, Paris.
14. Green J. On death from chloroform: its prevention by galvanism. Brit Med J 1871;1;551-3.
15. Duchenne GB. L'Electrisation Localisée. 1872. JB Baillière, Paris,

1102pp.

- 16.** Beard GM Rockwell AD. On the Medical and Surgical Uses of Electricity. 1891. W Wood & Co, New York, USA, 788pp.
- 17.** Theobald GW. The Electrical Stimulation of Labour. 1973. Butterworth, London, 93pp.
- 18.** Leduc S. Production of sleep and general and local anaesthesia by intermittent current of low voltage. Arch d'Electric Med 1902:10;617-21.
- 19.** Kirsch DL. Cranial electrotherapy stimulation, a safe and effective treatment for anxiety: a review of the literature. Medical Scope Monthly 1996:3(1);1-26.
- 20.** Melzack R Wall PD. Pain mechanisms: A new theory. Science (Wash) 1965:150(3699);971-9.
- 21.** Shealy CN Mortimer JT & Reswick JB. Electrical inhibition of pain by stimulation of the dorsal columns. Preliminary clinical report. Anesth Analgesia 1967:46; 489-1.
- 22.** Shealy CN Mortimer JT & Hagfors NR. Dorsal column electroanalgesia. J Neurosurg 1970:32; 560-4.
- 23.** Nashold BS Friedman H. Dorsal column stimulation for the control of pain. Preliminary report on 30 patients. J Neurosurg 1972:36; 590-7.
- 24.** Shealy CN Maurer D. Transcutaneous nerve stimulation for control of pain. Surg Neurology 1974:2; 45-7.
- 25.** Wall PD Sweet WH. Temporary abolition of pain in man. Science (Wash)1967:155; 108-9.
- 26.** Long DM. External electrical stimulation as a treatment of chronic pain. Minn Med 1974:57; 195-8.

Section 2

- 1.** Beecher H. Measurement of Subjective Responses. 1959, Oxford University Press, Oxford, 494pp.
- 2.** Sternbach RA Wolf SR Murphy RW *et al.* Aspects of chronic low back pain. Psychosomatics 1974:14;52-6.
- 3.** Paxton SL. Clinical uses of TENS - survey of physical therapists. Phys Ther 1980:60;38-44.
- 4.** Stonnington HH Stillwell GK & Ebersold MJ. Transcutaneous electrical stimulation for chronic pain relief - pilot study. Minn Med 1976:49;681-83.

5. Thorsteinsson G Stonnington HH Stillwell GK *et al.* The placebo effect of transcutaneous electrical stimulation. *Pain* 1978;5;31-41.
6. van der Ark G McGrath KA. Transcutaneous electrical stimulation in treatment of postoperative pain. *Am J Surg* 1975;130;338-40.
7. Thorsteinsson G Stonnington HH Stillwell GK *et al.* Transcutaneous electrical stimulation: double-blind trial of its efficacy for pain. *Arch Phys Med Rehabil* 1977;58;8-13.
8. Long DM Hagfors N. Electrical stimulation in the nervous system: the current status of electrical stimulation of the nervous system for relief of pain. *Pain* 1975;1;109-23.
9. Merskey H. Pain terms: a list with definitions and notes on usage. International Association for the Study of Pain. *Pain* 1979;6;73-9.
10. Melzack R Wall PD. Pain mechanisms: A new theory. *Science, Washington* 1965;150 (3699); 971-9.
11. Melzack R. Prolonged relief of pain by brief, intense, transcutaneous somatic stimulation. *Pain* 1975;1;357-73.
12. Melzack R Wall PD. *The Challenge of Pain*. 1982, Penguin Books Ltd, Harmondsworth, UK.
13. Melzack R Loeser JD. Phantom body pain in paraplegics; evidence for a central "pattern generating mechanism" for pain. *Pain* 1978;4;195-210.
14. Melzack R. *The Puzzle of Pain*. 1973, Penguin Books Ltd., Harmondsworth, UK.
15. Livingstone WK. *Pain Mechanisms*. 1943, MacMillan, New York.
16. Garrison DW Foreman RD. Decreased activity of spontaneous and noxiously evoked dorsal horn cells during transcutaneous electrical nerve stimulation (TENS). *Pain* 1994;58;309-1.
17. Nathan P W. The gate-control theory of pain; a critical review. *Brain* 1976;99;123-58.
18. Le Bars D Dickenson A & Besson JM. Diffuse noxious controls (DNHC). I & 11. *Pain* 1979;6;283-327.
19. Hughes J. Isolation of an endogenous compound from the brain with pharmacological properties similar to morphine. *Brain Res* 1975;88;295-308.
20. Weber E Geis R Voigt KH Barchas *et al.* Levels of pro-neo-endorphin/dynorphin-derived peptides in the hypothalamo-posterior pituitary system of male and female Brattleboro rats. *Brain Res* 1983;260(1);166-71 .

- 21.** Pomeranz B Chui D. Naloxone blockade of acupuncture analgesia; endorphin implicated. *Life Sci* 1976;19;1757-62.
- 22.** Mayer DJ Price DD & Raffii A. Antagonism of acupuncture analgesia in man by the narcotic antagonist naloxone. *Brain Res* 1977;121;368-72.
- 23.** Sjölund B Terenius L & Eriksson M. Increased cerebrospinal fluid levels of endorphin after electro-acupuncture. *Acta Physiol Scand* 1977;100;382-84.
- 24.** Cheng R Pomeranz B. Electroacupuncture analgesia is mediated by stereo specific opiate receptors and is reversed by antagonists of type 1 receptors. *Life Sci* 1979;26;631-9.
- 25.** Pomeranz B Cheng R. Suppression of noxious responses in single neurons of cat spinal cord by electroacupuncture and its reversal by the opiate antagonist naloxone. *Experiment Neurol* 1979;64;327-41.
- 26.** Martin WR. Opioid antagonists. *Pharmacol Res* 1967;19;463-521.
- 27.** Marx JL. Analgesia: how the body inhibits pain perception. *Science (Washington)* 1977;196;471.
- 28.** Hayes R Price DD & Dubner R. Naloxone antagonism as evidence for narcotic mechanisms. *Science* 1977;196;600.
- 29.** Millan MJ Czlonkowski A & Herz A. Evidence that μ -opioid receptors mediate midbrain "stimulation-produced-analgesia" in freely moving rats. *Neuroscience* 1987;22;885-96.
- 30.** Woolf CJ Wall PD. Endogenous opioid peptides and pain mechanisms; a complex relationship. *Nature, London* 1983;306;739-40.
- 31.** Clement-Jones VV McLoughlin L Tomkin S *et al.* Increased β -endorphin but not met-enkephalin levels in human cerebro-spinal fluid after acupuncture for recurrent pain. *Lancet ii* 1980: 946-9.
- 32.** Nappi G Facchine F Bone G *et al.* Plasma opioid levels in post traumatic chronic headache and trigeminal neuralgia; maintained responses to acupuncture. *Headache* 1982;22;276-9.
- 33.** Fachinetti F Sandrini G Petraglia F *et al.* Concomitant increase in nociceptor flexion reflex threshold and plasma opioids following transcutaneous electrical nerve stimulation. *Pain* 1984;19;295-303.
- 34.** Johnston MI Ashton CH & Thompson JW. A Prospective investigation into factors related to patient response to transcutaneous electrical nerve stimulation (TENS) - the importance of cortical responsivity. *Eur J Pain* 1993;1;1-9.

- 35.** Chen XH Han JS. All three types of opioid receptors in the spinal cord are important for 2/15 Hz electroacupuncture analgesia. *Eur J Pharmacol* 1992;211;203-10.
- 36.** Malizia F Paolucci D. Electroacupuncture and peripheral beta-endorphin and ACTH levels. *Lancet* ii 1979;535-36.
- 37.** Masala A Satta G Alagena S *et al.* Suppression of electroacupuncture (EA)-induced beta-endorphin and ACTH release by hydrocortisone in man. Absence of effects on EA-induced anaesthesia. *Acta Endocrinol* 1983;103;469-72.
- 38.** Nappi G Facchine F Bono G *et al.* Different releasing effects of traditional manual and electroacupuncture on propiopiocortin-related peptides. *Acupunct Electrother Res* 1982;7;93-103.
- 39.** Clement-Jones VV (1982). Clinical studies with endorphin- and non-endorphin-related opioids. In: *Neuropeptides: Basic and Clinical Aspects*. Eds. Flink G Whalley LJ, Churchill Livingstone, Edinburgh.
- 40.** Han JS Xie GA Zhou ZL *et al.* Acupuncture mechanisms in rabbits studied with micro-injections of antibodies against β -endorphin, enkephalin and substance P. *Neuropharmacology* 1984;23;1-6.
- 41.** Han JS Chen XH Sun SG *et al.* Effect of low- and high-frequency TENS on Met-enkephalin-Arg-Phe and dynorphin A immunoreactivity in human lumbar CSF. *Pain* 1991;47;295-8.
- 42.** Vazquez J Munoz M & Luque MA. Modifications of the distribution of substance P-like immunoreactivity in the cerebral basal nuclei of the cat after electroacupuncture. *Histol Histopathol* 1993;8(3);557-60.
- 43.** Auriacombe M Tignol J LeMoal M *et al.* Transcutaneous electrical stimulation with Limoge current potentiates morphine analgesia and attenuates opiate abstinence syndrome. *Biol Psychiatr* 1990;28;650-56.
- 44.** Ng LYK Douhill TC Thoa NB *et al.* Modification of morphine withdrawal syndrome in rats following transauricular electrostimulation; an experimental paradigm for auricular electroacupuncture. *Biol Psych* 1995;10;575-80.
- 45.** Choy YM Tso WW Feng KP *et al.* Suppression of narcotic withdrawal and ACTH in plasma by auricular electro-acupuncture. *Biochim Biophys Commun* 1978;82;305-9.
- 46.** Cheng RSS Pomeranz B & Yu G. Electro-acupuncture treatment of morphine dependent mice decreases symptoms of withdrawal without cross-tolerance. *Eur J Pharmacol* 1980;68;477-82.
- 47.** Clement-Jones VV McLoughlin L Lowry PJ *et al.* Acupuncture and

heroin addicts: changes in met-enkephalin and β -endorphin in blood and cerebrospinal fluid. *Lancet* ii 1979;380-3.

48. Shimizu T Koja T. Effects of methysergide and naloxone on analgesia produced by peripheral electrical stimulation in mice. *Brain Res* 1981;208;463-7.

49. Cheng RSS Pomeranz B. Monoaminergic mechanisms of electroacupuncture analgesia. *Brain Res* 1981;215;77-92.

50. Zhang AZ Shen YC. Changes in levels of monoamine neurotransmitters and their main metabolites in rat brain after electroacupuncture treatment. *Int J Neurosci* 1981;15;147-9.

51. Tsai HY Lin JG & Inoki R. Further evidence for possible analgesic mechanisms of electroacupuncture: effects of neuropeptides and serotonergic neurons in rat spinal cord. *Jpn J Pharmacol* 1989;49;181-5.

52. Capel ID Goode AG Smallwood AE *et al.* . Tryptophan, serotonin and hydroxyindole acetic acid levels in rats following fast frequency electrostimulation. *ICRS Med Sci* 1982;10;427-8.

53. Han CS Chou PH Lu CC *et al.* The rôle of central 5-HT in acupuncture analgesia. *Sci Sin* 1979;22;91-104.

54. McLennan H Gilfillan K & Heap Y. Some pharmacological observations on the analgesia induced by acupuncture. *Pain* 1977;3;229-38.

55. Liu X Zhu B. Relationship between electroacupuncture analgesia and descending pain inhibitory mechanism of nucleus raphe magnus. *Pain* 1986;24;383-96.

56. Zao FY Han JS. Acupuncture analgesia in impacted last molar extraction. Effect of clomipramine and pargyline. In: *The Neurochemical Basis of Pain Relief By Acupuncture. A Collection of Papers 1973-89.* Ed. Han JS, Beijing Medical College, Beijing, 1987:96-7.

57. Han JS Terenius L. Neurochemical basis of acupuncture analgesia. *Ann Rev Toxicol* 1982; 22;91-104.

58. Anderson SA Eriksson T Holmgren E *et al.* Electroacupuncture. Effect on pain threshold measured with electrical stimulation of teeth. *Brain Res* 1973;63;393-6.

59. Cheng RSS Pomeranz B. Electroacupuncture analgesia could be mediated by two pain-relieving mechanisms: endorphin and non-endorphin systems. *Life Sci* 1979;25(23);1957-62.

60. Pert A Dionne R Ng L *et al.* Alterations in rat CNS endorphins

following transauricular electroacupuncture. *Brain Res* 1981;224(1);83-94.

61. Chapman C Bendetti C. Analgesia following transcutaneous electrical stimulation and its partial reversal by a narcotic antagonist. *Life Sci* 1977;21(11); 1645-8.

62. Sjölund SH Eriksson MBE The influence of naloxone on analgesia produced by peripheral conditioning stimulation. *Brain* 1979;173;295-301.

63. O'Brien WJ Rutan FM Sanborn C *et al.* (1984). Effect of transcutaneous electrical nerve stimulation on human blood beta-endorphin levels. *Phys Ther* 1984;64(9);1367-74.

64. Hughes FS Lichstein PR Whitlock D *et al.* Response of plasma beta-endorphin to transcutaneous electrical nerve stimulation in healthy subjects. *Phys Ther* 1984;64(7);1062-6.

65. Ashton H Ebenezer I Golding JF *et al.* Effects of acupuncture and transcutaneous electrical nerve stimulation on cold-induced pain in normal subjects. *J Psychosom Res* 1984;28;301-8.

66. Johnston MI Ashton CH Bousfield *et al.* Analgesic effects of different frequencies of transcutaneous electrical nerve stimulation on cold-induced pain in normal subjects. *Pain* 1989;39;329-34.

67. Dent RRM Guilleminault C & Albert LH. Diurnal rhythm of plasma immunoreactive beta endorphin and its relationship to sleep and plasma rhythms of cortisol and prolactin. *J Clin Endocrinol Metab* 1981;52;942-7.

68. Ruff MR Pert CB Weber RJ *et al.* Benzodiazepine receptor-mediated chemotaxis of human monocytes. *Science*, Washington 1985;229;1281.

69. Pert CB Ruff MR Weber RJ *et al.* Neuropeptides and their receptors: a psychosomatic network. *J Immunol* 1985;135;820s-826s.

70. Riedere PH Tenk HW. Manipulation of neurotransmitters by acupuncture. *J Neural Trans* 1975;37;81-94.

71. Aso R Motohashi M Murata M *et al.* The influence of acupuncture stimulation on plasma level of LH, FSH, progesterone and estradiol in normally ovulating women. *Am J Chin Med* 1976;4;391-401.

72. Cheng R McKibbin L Roy B *et al.* Electroacupuncture elevates blood cortisol levels in naive horses; sham treatment has no effect. *Int J Neurosci* 1980;10(2-3);95-7.

73. Chin TF Lin JG & Wang SY. Induction of circulating interferon in

humans by acupuncture. *Am J Acupunct* 1988;16(4);319-22.

74. Vasilenko AM *et al.* Prevention and correction of stress-induced immunodeficiency by atrial electroacupuncture. *Patol Fiziol Eksp Ter* 1989;(3); 21-4.

75. Lundeberg T Eriksson SV & Theodorsson E. Neuroimmunomodulatory effects of acupuncture in mice. *Neurosci Lett* 1991;128(2);161-4.

76. Ouyang Q Cao M & Cao Q. An observation on the effect of moxibustion on an immunological function in 69 cases of lung cancer. *Int J Clin Acupunct* 1992;3(1);361-73.

77. Zun HG Jin DZ. Effects of acupuncture on immunoglobulins in patients with asthma and rheumatoid arthritis. *J Tradit Chin Med* 1995;15(2);102-5.

78. Guo C Zhang W Zheng S *et al.* Clinical observation on efficacy of electroacupuncture therapy in hyperplasia of mammary glands and its effect on immunological function. *J Tradit Chin Med* 1996;16(4);281-7.

79. Nordenström BEW. Clinical, Experimental and Theoretical Evidence for an Additional Circulatory System. 1983, Nordic Medical Publications, Stockholm, Sweden 358pp.

80. Szent-Györgyi A. Introduction to Submolecular Biology. 1960, Academic Press, New York.

81. Szent-Györgyi A. Bioelectronics. 1968, Academic Press, New York p79.

82. Martin AJP. Tribo-electricity in wool and hair. *Proc Phys Soc* 1941: 53;186-9.

83. Fukada E Yasuda I. On the piezoelectric effect of bone. *J Phys Soc Japan* 1957;12;1158-62.

84. Marino AA Becker RO. Piezoelectric effects and growth control in bone. *Nature (Lond)* 1970;228;473.

85. Marino AA Soderholm SC & Becker RO. Origin of the piezoelectric effect in bone. *Calc Tissue Res* 1971;8;177.

86. Lang S (1966). Pyroelectric effect in bone and tendon, *Nature (Lond)* 212, 704-5.

87. Athenstaedt H. Permanent electric polarisation and pyroelectric behavior of the vertebrate skeleton. *Z Zellforsch* 1974;97; 537.

88. Fukada E Takamaster T & Yusada I. Callus formation by electret. *Jap J Appl Phys* 1975;14; 2079-85.

89. Shamos MH Lavine LS. Piezoelectricity as a fundamental property

of biological tissue. *Nature(London)* 1967:213; 627-8.

90. Caserta G Cergvini T. Piezoelectric transducer model for phosphorylation in photosynthetic membranes. *J Theoret Biol* 1973:41; 127.

91. Caserta G Cergvini T. Piezoelectric theory of enzyme catalysis as inferred from the electromechanical principles of bioenergetics. *Proc Natl Acad Sci* 1974:71;4421-4.

92. Gözela AN Akacasu A. A piezoelectric model for nerve conduction. *Ann NY Acad Sci* 1974:238;342-4.

93. Nuccitelli R. Ionic currents in morphogenesis. *Experientia* 1988: 44;657-66.

94. Yancey SB Biswal S & Revel JP. Spatial and temporal patterns of distribution of the gap junction protein connexin-43 during mouse gastrulation and organogenesis. *Development* 1992:114;203-12.

95. Jaffe LF. Electrophoresis along cell membranes. *Nature(London)* 1977:265;600-2.

96. Shang C. Singular point, organising centre and acupuncture point. *Am J Chin Med* 1989:17;119-27.

97. Hameroff SR. Coherence in the cytoskeleton: implication for biological information processing. In: *Biological Coherence and Responses to External Stimuli*. Ed. Frölich H, 1988, Springer Verlag, Berlin, 242.

98. Becker RO. The basic biological data transmission and control system influenced by electrical forces. *Ann NY Acad Sci* 1974:238; 236-41.

99. Becker RO. Electrical control systems and regenerative growth. *J Bioelectr* 1982:1(2); 239-64.

100. Nias DK. The therapeutic effect of low-level direct electrical currents. *Psychol Bull* 1976: 83;766.

101. Libet B Gerard RW. An analysis of some correlates of steady potentials in mammalian cortex. *Electroenceph Clin Neurophysiol* 1962: 14; 445.

102. Becker RO. *Cross Currents. The Promise of Electromedicine, the Perils of Electropollution*. 1990, Jeremy Tharcher Inc, Los Angeles.

103. Becker RO. The bioelectric field pattern in the salamander and its simulation by an electrical analogue. *IEEE Trans Med Electron ME* 1960:7;202.

104. Becker RO. Proof that the direct electrical currents in the

salamander are semiconducting in nature. *Science* 1961;134:101-2.

105. Motoyama H. Electrophysiological and preliminary biochemical studies of skin properties in relation to the acupuncture meridian. *Int Assoc Religion Parapychol* 1980;6;1-36.

106. Ward-Baskin I Flowerdew MW. Thoughts on new approaches to pains with no apparent cause. 1. *JCPPP Winter* 1987; 2.

107. Ho MW Knight DP. The acupuncture system and liquid crystal collagen fibers of the connective tissue. *Am J Chin Med* 1998;24 (3/4); 251-63.

108. Clegg JS Drost-Hansen W. On the biochemistry and cell physiology of water. In: *Biochemistry and Molecular Biology of Fishes*. I. 1991; Elsevier Science Publications, pp1-23.

109. Ingber DE. The architecture of life. *Sci Am*, January 1998;48-57.

110. Jaffe LF. Development currents, voltages and gradients. In: *Development Order: Its Origins and Regulation*. Eds. Subteiny S, Green PD, 1982, Alan R Liss, New York, pp183-215.

111. Borgens RB Venable JW & Jaffe LF. Bioelectricity and regeneration: large currents leave the stumps of regenerating newt limbs. *Proc Natl Acad Sci USA* 1977;74;4528-32.

112. Borgens RB Rouleau MF & DeLanny LE. A steady efflux of ionic current predicts hind-limb development in the axolotl. *J Exper Zool* 1983;228;493-503.

113. Illingworth C Barker AT. Measurement of electrical current emerging during regeneration of amputated finger tips in children. *Clin Phys Physiol Measurement* 1980;1;87-9.

Section 4

1. Nelson RM Currier DP. *Clinical Electrotherapy*. 1991, Appleton and Lange, New Jersey, USA, p306.

2. McQuay HJ Moore RA Eccleston C et al. Systematic review of outpatient services for chronic pain control. *Health Technol Assess* 1997;1(6);i-iv,1-135.

3. Nesheim BI. The use of transcutaneous nerve stimulation for pain relief during labour. A controlled clinical study. *Acta Obstet Gynecol Scand* 1981;60(1),13-6.

4. Thomas IL Tyle V & Webster J. An evaluation of transcutaneous electrical nerve stimulation for pain relief in labour. *Aust NZ J Obstet Gynaecol* 1988;28(3);182-9.

5. Lee EW Chung IW Lee JY et al. The role of transcutaneous

electrical nerve stimulation in management of labour in obstetric patients. *Asia Oceania J Obstet Gynaecol* 1990;16(3);247-54.

6. Chia YT Arulkumaran S Chua S *et al.* Effectiveness of transcutaneous electric nerve stimulator for pain relief in labour. *Asia Oceania J Obstet Gynaecol* 1990;16(2);145-51.

7. van der Ploeg JM Vervest HA Liem AL *et al.* Transcutaneous nerve stimulation (TENS) during the first stage of labour: a randomised clinical trial. *Pain* 1996;68(1);75-8.

8. Robson JE. Transcutaneous nerve stimulation for pain relief in labour. *Anaesthesia* 1979;34(4);357-60.

9. Dunn PA Rogers D & Halford K. Transcutaneous electrical nerve stimulation at acupuncture points in the induction of uterine contractions. *Obstet Gynecol* 1989;73(2);286-90.

10. Augustinsson L Bohlin P Bundsen P *et al.* Pain relief during delivery by transcutaneous electrical nerve stimulation. *Pain* 1977;4;59-65.

11. Stewart P. Transcutaneous nerve stimulation as a method of analgesia in labour. *Anaesthesia* 1979;34(4);361-4.

12. Miller-Jones CM. Transcutaneous nerve stimulation in labour. 1980;35(4);372-5.

13. Grim LC Morey SH. Transcutaneous electrical nerve stimulation for relief of parturition pain. A clinical report. *Phys Ther* 1985;65(3);337-40.

14. Bundsen P Peterson LE & Selstam U. Pain relief during labour by Transcutaneous Electrical Nerve Stimulation: a prospective study. *Acta Obstet Gynæ Scand* 1981;60(5);459-68.

15. Kaplan B Rabinerson D Lurie S *et al.* Transcutaneous electrical nerve stimulation (TENS) for adjuvant pain-relief during labour and delivery. *Int J Gynaecol Obstet* 1998;60(3);251-5.

16. Bundsen P Ericson K. Pain relief in labour by transcutaneous electrical nerve stimulation. Safety aspects. *Acta Obstet Gynecol Scand* 1982;61(1);1-5.

17. Bundsen P Ericson K Peterson LE *et al.* Pain relief in labour by transcutaneous electrical nerve stimulation. Testing of a modified stimulation technique and evaluation of the neurological and biochemical condition of the newborn infant. *Acta Obstet Gynecol*

Scand 1982:61(2);129-36.

18. Labrecque M Nouwen A Bergeron M *et al.* A randomised controlled trial of nonpharmacologic approaches for relief of low back pain during labour. J Fam Pract 1999;48(4);259-63.

19. Harrison RF Woods T Shore M *et al.* Pain relief in labour using transcutaneous electrical nerve stimulation (TENS). A TENS/TENS placebo controlled study in two parity. Br J Obstet Gynaecol 1986;93(7);739-46.

20. Harrison RF Shore M Woods T *et al.* A comparative study of transcutaneous electrical nerve stimulation (TENS), entonox, pethidine + promazine and lumbar epidural for pain relief in labour. Acta Obstet Gynecol Scand 1987;66(1);9-14.

21. Lee EW Chung IW Lee JY *et al.* The role of transcutaneous electrical nerve stimulation in management of labour in obstetric patients. Asia Oceania J Obstet Gynaecol 1990;16(3);247-54.

22. Tsen LC Thomas J Segal S *et al.* Transcutaneous electrical nerve stimulation does not augment combined spinal epidural labour analgesia. Can J Anaesth 2000;47(1);38-42.

22a. van der Spank JT, Cambier DC, De Paepe HM, *et al.* Pain relief in labour by transcutaneous electrical nerve stimulation (TENS). Arch Gynecol Obstet 2000;264(3);131-6

23. Smith CM Guralnick MS Gelfand MM *et al.* The effects of transcutaneous electrical nerve stimulation on post-cesarean pain. Pain 1986;27(2);181-93.

24. Reynolds RA Gladstone N & Ansari AH. Transcutaneous electrical nerve stimulation for reducing narcotic use after cesarean section. J Reprod Med 1987;32(11);843-6.

25. Carroll D Tramèr M, McQuay H *et al.* Transcutaneous electrical nerve stimulation in labour pain: a systematic review. Br J Obstet Gynaecol 1997;104(2);169-7.

26. Reeve J Menon D & Corabian P. Transcutaneous electrical nerve stimulation (TENS): a technology assessment. Int J Technol Assess Health Care 1996;12(2);299-324.

27. Walsh DM. TENS: Clinical Applications and Related Theory. 1997, Churchill Livingstone, Edinburgh, p118.

28. Skelton I. Two non-pharmacological forms of pain relief in labour.

Pt 1. Acupuncture. *Int Perspect Phys Ther* 3, Obstetrics and Gynaecology, 1988; 129-40.

29. Cotter DJ. Overview of transcutaneous electrical nerve stimulation for treatment of acute postoperative pain. *Med Instrum* 1983;17(4);289-92.

30. Carroll D Tramèr M McQuay H *et al.* Randomization is important in studies with pain outcomes: systematic review of transcutaneous electrical nerve stimulation in acute postoperative pain. *Br J Anaesth* 1996;77(6);798-803.

31. Galloway DJ Boyle P Burns HJ *et al.* A clinical assessment of electroanalgesia following abdominal operations. *Surg Gynecol Obstet* 1984;159(5);453-6.

32. Reuss R Cronen P & Abplanalp L. Transcutaneous electrical nerve stimulation for pain control after cholecystectomy: lack of expected benefits. *South Med J* 1988;81(11);1361-3.

33. Laitinen J Nuutinen L. Failure of transcutaneous electrical nerve stimulation and indomethacin to reduce opiate requirement following cholecystectomy. *Acta Anaesthesiol Scand* 1991;35(8);700-5.

34. Lagas HM Zuurmond WW & Smith-van Rietschoten W. Transcutaneous nerve stimulation for the treatment of postoperative pain. *Acta Anaesthesiol Belg* 1984;35 Suppl;253-7.

35. McCallum MI Glynn CJ Moore RA *et al.* Transcutaneous electrical nerve stimulation in the management of acute postoperative pain. *Br J Anaesth* 1988;61(3);308-12.

36. Walker RH Morris BA Angulo DL *et al.* Postoperative use of continuous passive motion, transcutaneous electrical nerve stimulation, and continuous cooling pad following total knee arthroplasty. *J Arthroplasty* 1991;6(2);151-6.

37. Smedley F Taube M & Wastell C. Transcutaneous electrical nerve stimulation for pain relief following inguinal hernia repair: a controlled trial. *Eur Surg Res* 1988;20(4);233-7.

38. Stubbing JF Jellicoe JA. Transcutaneous electrical nerve stimulation after thoracotomy. Pain relief and peak expiratory flow rate--a trial of transcutaneous electrical nerve stimulation. *Anaesthesia* 1988;43(4);296-8.

39. Solomon RA Viernstein MC & Long DM. Reduction of

postoperative pain and narcotic use by transcutaneous electrical nerve stimulation. *Surgery* 1980;87(2);142-6.

40. Sodipo JO Adediji SA & Olumide O. Postoperative pain relief by transcutaneous electrical nerve stimulation (TENS). *Am J Chin Med* 1980;8(1/2);190-4.

41. Pike PM. Transcutaneous electrical stimulation. Its use in the management of postoperative pain. *Anaesthesia* 1978;33(2);165-71.

42. Navarathnam RG Wang IY Thomas D *et al.* Evaluation of the transcutaneous electrical nerve stimulator for postoperative analgesia following cardiac surgery. *Anaesth Intensive Care* 1984;12(4);345-50.

43. Lim AT Edis G Kranz H *et al.* Postoperative pain control: contribution of psychological factors and transcutaneous electrical stimulation. *Pain* 1983;17(2);179-88.

44. Conn IG Marshall AH Yadav SN *et al.* Transcutaneous electrical nerve stimulation following appendicectomy: the placebo effect. *Ann R Coll Surg Engl* 1986;68(4);191-2.

45. Gilbert JM Gledhill T Law N *et al.* Controlled trial of transcutaneous electrical nerve stimulation (TENS) for postoperative pain relief following inguinal herniorrhaphy. *Br J Surg* 1986 ;73(9);749-51.

46. Finsen V Persen L Lovlien M *et al.* Transcutaneous electrical nerve stimulation after major amputation. *J Bone Joint Surg* 1988 :70(1);109-12.

47. Wang B Tang J White PF *et al.* Effect of the intensity of transcutaneous acupoint electrical stimulation on the postoperative analgesic requirement. *Anesth Analg* 1997: 85(2);406-13.

48. Chen L Tang J White PF *et al.* The effect of location of transcutaneous electrical nerve stimulation on postoperative opioid analgesic requirement: acupoint versus nonacupoint stimulation. *Anesth Analg* 1998;87(5);1129-34.

49. Hamza MA White PF Ahmed HE *et al.* Effect of the frequency of transcutaneous electrical nerve stimulation on the postoperative opioid analgesic requirement and recovery profile. *Anesthesiology* 1999;91(5);1232-8.

50. Mannheimer JS. Electrode placement for transcutaneous electrical nerve stimulation. *Phys Ther* 1978;58(1);1645-8.

- 51.** Harvie KW. A major advance in the control of postoperative knee pain. *Orthopedics Rev* 1979;7;121-3.
- 52.** Stubbing JF Jellicoe JA. Transcutaneous electrical nerve stimulation after thoracotomy. Pain relief and peak expiratory flow rate--a trial of transcutaneous electrical nerve stimulation. *Anaesthesia* 1988;43(4);296-8.
- 53.** Dundee JW McMillan CM. Clinical uses of P6 acupuncture antiemesis. *Acupunct Electrother Res* 1990;15(3-4);211-5.
- 54.** Lee A Done ML. The use of nonpharmacologic techniques to prevent postoperative nausea and vomiting: a meta-analysis. *Anesth Analg* 1999; 88(6);1362-9.
- 55.** Fassoulaki A Papilas K Sarantopoulos C *et al.* Transcutaneous electrical nerve stimulation reduces the incidence of vomiting after hysterectomy. *Anesth Analg* 1993;76(5);012-4.
- 56.** Pearl ML Fischer M McCauley DL *et al.* Transcutaneous electrical nerve stimulation as an adjunct for controlling chemotherapy-induced nausea and vomiting in gynecologic oncology patients. *Cancer Nurs* 1999;22(4);307-11.
- 57.** Evans AT Samuels SN Marshall C *et al.* Suppression of pregnancy-induced nausea and vomiting with sensory afferent stimulation. *J Reprod Med* 1993;38(8);603-6.
- 58.** Milsom I Hedner N & Mannheimer C. A comparative study of the effect of high-intensity transcutaneous nerve stimulation and oral naproxen on intrauterine pressure and menstrual pain in patients with primary dysmenorrhea. *Am J Obstet Gynecol* 1994;170(1);123-9.
- 59.** Kaplan B Peled Y Pardo J *et al.* Transcutaneous electrical nerve stimulation (TENS) as a relief for dysmenorrhea. *Clin Exp Obstet Gynecol* 1994;21(2);87-9.
- 60.** Kaplan B Rabinerson D Lurie S *et al.* Clinical evaluation of a new model of a transcutaneous electrical nerve stimulation device for the management of primary dysmenorrhea. *Gynecol Obstet Invest* 1997;44(4);255-9.
- 61.** Lewers D Clelland JA Jackson JR *et al.* Transcutaneous electrical nerve stimulation in the relief of primary dysmenorrhea. *Phys Ther* 1989;69(1);3-9.
- 62.** Lundeberg T Bondesson L & Lundström V. Relief of primary

dysmenorrhea by transcutaneous electrical nerve stimulation. *Acta Obstet Gynecol Scand* 1985;64(6);491-7.

63. Dawood MY Ramos J. Transcutaneous electrical nerve stimulation (TENS) for the treatment of primary dysmenorrhea: a randomised crossover comparison with placebo TENS and ibuprofen. *Obstet Gynecol* 1990;75(4);656-60.

64. Kleier DJ Stoller NH. An evaluation of the clinical analgesia/anesthesia efficacy on acute pain using the high frequency neural modulator in various dental settings. *Oral Surg Oral Med Oral Pathol* 1987;63(4);501-5.

65. Hochman R. Neurotransmitter modulator (TENS) for control of dental operative pain. *JADA* 1988;116; 208-12.

102. Estafan DJ. Invasive and noninvasive dental analgesia techniques. *J Gen Dent* 1998;46(6);600-3.

66. Clark MS Silverstone LM Lindenmouth J *et al.* An evaluation of the clinical analgesia/anesthesia efficacy on acute pain using the high frequency neural modulator in various dental settings. *Oral Surg Oral Med Oral Pathol* 1987;63; 501-5.

67. Malamed SF Quinn CL, Trent Torgersen R *et al.* Electronic dental anesthesia for restorative dentistry. *Anesth Prog* 1989;36;192-200.

68. Persson J Köch G & Kurol J. Comparison of electronic dental anaesthesia (Equinox™) and conventional LA in cavity preparation and partial pulpectomy. 13th Congress Int Assoc Dent for Children, Kyoto, Japan September, 1991.

69. Yap AU Ho HC. Electronic and local anesthesia: a clinical comparison for operative procedures. *Quintessence Int* 1996;27(8);549-53.

70. Abdulhameed SM Feigal RJ Rudney JD *et al.* Effect of peripheral electrical stimulation on measures of tooth pain threshold and oral soft tissue comfort in children. *Anesth Prog* 1989;36(2);52-7.

71. teDuits E Goepferd S Donly K *et al.* The effectiveness of electronic dental anesthesia in children. *Pediatr Dent* 1993;15(3);191-6.

72. Oztas N Olmez A & Yel B. Clinical evaluation of transcutaneous electronic nerve stimulation for pain control during tooth preparation. *Quintessence Int* 1997;28(9);603-8.

73. Modaresi A Lindsay SJ Gould A *et al.* A partial double-blind,

placebo-controlled study of electronic dental anaesthesia in children. *Int J Paediatr Dent* 1996;6(4);245-51.

74. Harvey M Elliott M. Transcutaneous electrical nerve stimulation (TENS) for pain management during cavity preparations in pediatric patients. *ASDC J Dent Child* 1995;62(1);49-51.

75. Hansson P Ekblom A. Afferent stimulation induced pain relief in acute oro-facial pain and its failure to induce sufficient pain reduction in dental and oral surgery. *Pain* 1984;20(3);273-8.

76. Hansson P Ekblom A. Transcutaneous electrical nerve stimulation (TENS) as compared to placebo TENS for the relief of acute oro-facial pain. *Pain* 1983;15(2);157-65.

77. Ordog GJ. Transcutaneous electrical nerve stimulation versus oral analgesic: a randomised double-blind controlled study in acute traumatic pain. *Am J Emerg Med* 1987;5(1);6-10.

78. Clark MS Silverstone LM Lindenmuth J *et al.* An evaluation of the clinical analgesia/anesthesia efficacy on acute pain using the high frequency neural modulator in various dental settings. *Oral Surg Oral Med Oral Pathol* 1987;63(4);501-5.

79. Wilder-Smith P. Untersuchungen zur Schmerzunterdrückung mittels transkutaner elektrischer Nervenstimulation (TENS). *Dtsch Zahnarztl Z* 1990;45(6);356-9.

80. Meechan JG Gowans AJ & Welbury RR. The use of patient-controlled transcutaneous electronic nerve stimulation (TENS) to decrease the discomfort of regional anaesthesia in dentistry: a randomised controlled clinical trial. *J Dent* 1998;26(5/6);417-20.

81. Meechan JG Winter RA. A comparison of topical anaesthesia and electronic nerve stimulation for reducing the pain of intra-oral injections [see comments]. *Br Dent J* 1996;181(9);333-5.

82. Jacobs R van Steenberghe D. The effect of electronic dental analgesia during sonic scaling. *J Clin Periodontol* 1994;21(10);728-30.

83. Bremerich A Wiegel W Thein T *et al.* Transcutaneous electric nerve stimulation (TENS) in the therapy of chronic facial pain. Preliminary report. *J Craniomaxillofac Surg* 1988;16(8);379-81.

84. Linde C Isacsson G & Jonsson BG. Outcome of 6-week treatment with transcutaneous electric nerve stimulation compared with splint on symptomatic disk displacement without reduction. *Acta Odontol Scand*

1995:53(2);92-8.

85. Kruger LR van der Linden WJ & Cleaton-Jones PE. Transcutaneous electrical nerve stimulation in the treatment of myofascial pain dysfunction. *S Afr J Surg* 1998:36(1);35-8.

Section 6

1. Mannheimer JS Lampe G. *Clinical Transcutaneous Electrical Nerve Stimulation*, 1984, FA Davis & Co, Philadelphia, USA, pp. 57-62, 529-34.

2. Nelson RM Currier DP. *Clinical Electrotherapy*, 1991, Appleton and Lange, New Jersey, USA, pp. 268-9, 274-7.

3. Walsh DM. *TENS: Clinical Applications and Related Theory*, 1997, Churchill Livingstone, Edinburgh, pp. 5, 45-8, 55-7, 103-5.

Section 7

1. Robinson AJ. Transcutaneous electrical nerve stimulation for the control of pain in musculoskeletal disorders. *JOSPT* 1996:24(4);208-6.

2. Walsh DM. *TENS: Clinical Applications and Related Theory*, 1997, Churchill Livingstone, Edinburgh, 36-7.

3. Gadsby JG Flowerdew MW (1997). The effectiveness of transcutaneous electrical nerve stimulation (TENS) and acupuncture-transcutaneous electrical nerve stimulation (ALTENS) in the treatment of patients with chronic low back pain. In: Bombardier C, Nachemson A, Deyo R *et al.* Eds. *CMSG back module of the Cochrane database of systematic reviews*, Oxford: Update Software, The Cochrane Collaboration, issue 3.

<http://www.update-software.com/abstracts/ab000210.htm>

<http://www.cochrane.org/cochrane/revabstr/mainindex.htm>

4. Ulett GA Han S & Han JS, Electroacupuncture: mechanisms and clinical application. *Biol Psychiatry* 1998 Jul 15:44(2);129-38.

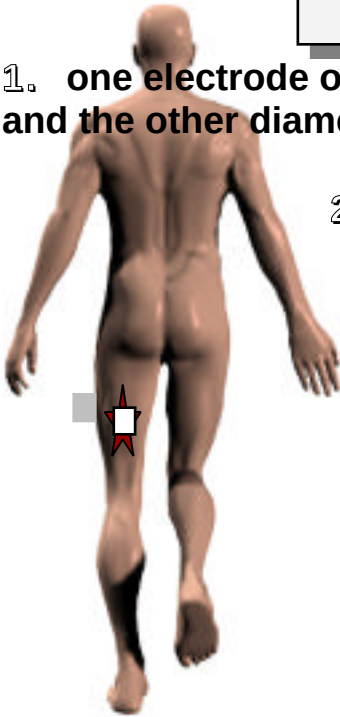
5. Ulett GA Han JS & Han S. Traditional and Evidence-Based Acupuncture: History, Mechanisms, and Present Status. *South Med J* 1998:91(12);1115-20.

Also see

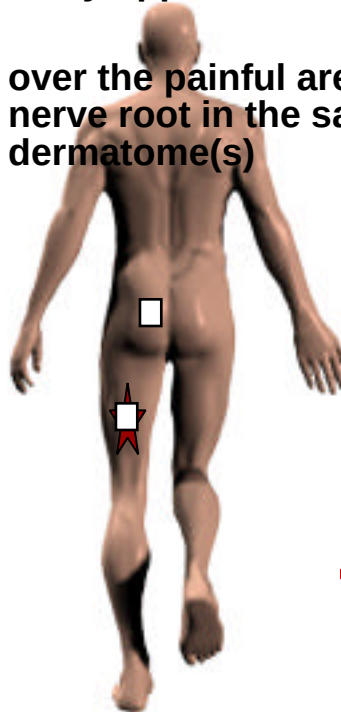
<http://www.medscape.com/SMA/SMJ/1998/v91.n12/smj9112.04.ulet/smj9112.04.u=let-01.html>

Electrode placement for localised pain - general principles

1. one electrode over pain and the other diametrically opposite

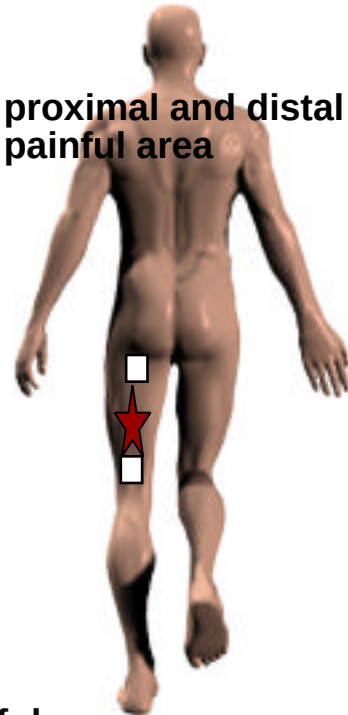


2. over the painful area and at the nerve root in the same dermatome(s)

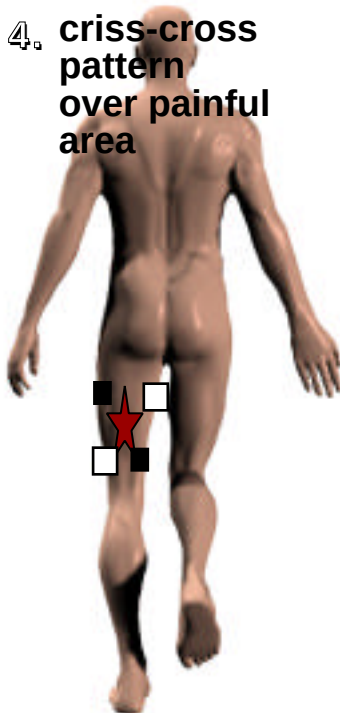


order of priority for positioning electrodes

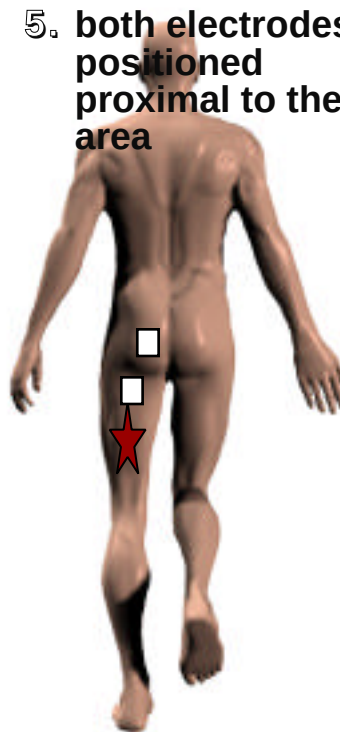
3. proximal and distal to painful area



4. criss-cross pattern over painful area



5. both electrodes positioned proximal to the painful area



6. both electrodes positioned distal to the painful area



Treatment regimes for subacute, acute and chronic pain

Pain

acute
subacute

chronic

2pps, 200µsec, comfortably strong intensity, 30min x3+ daily, 2/3 days

not effective

effective
continue

60-80pps, 80-100µsec, intensity produces distinct paræsthesia in pain area, 1h x2-3 daily

not effective

effective
continue

Rethink whole treatment strategy

60-80pps, 80-100µsec, intensity produces distinct paræsthesia in pain area, 1h x2-3 daily

effective
continue

not effective

Same parameters increase treatment length by hourly increments

effective
continue

not effective

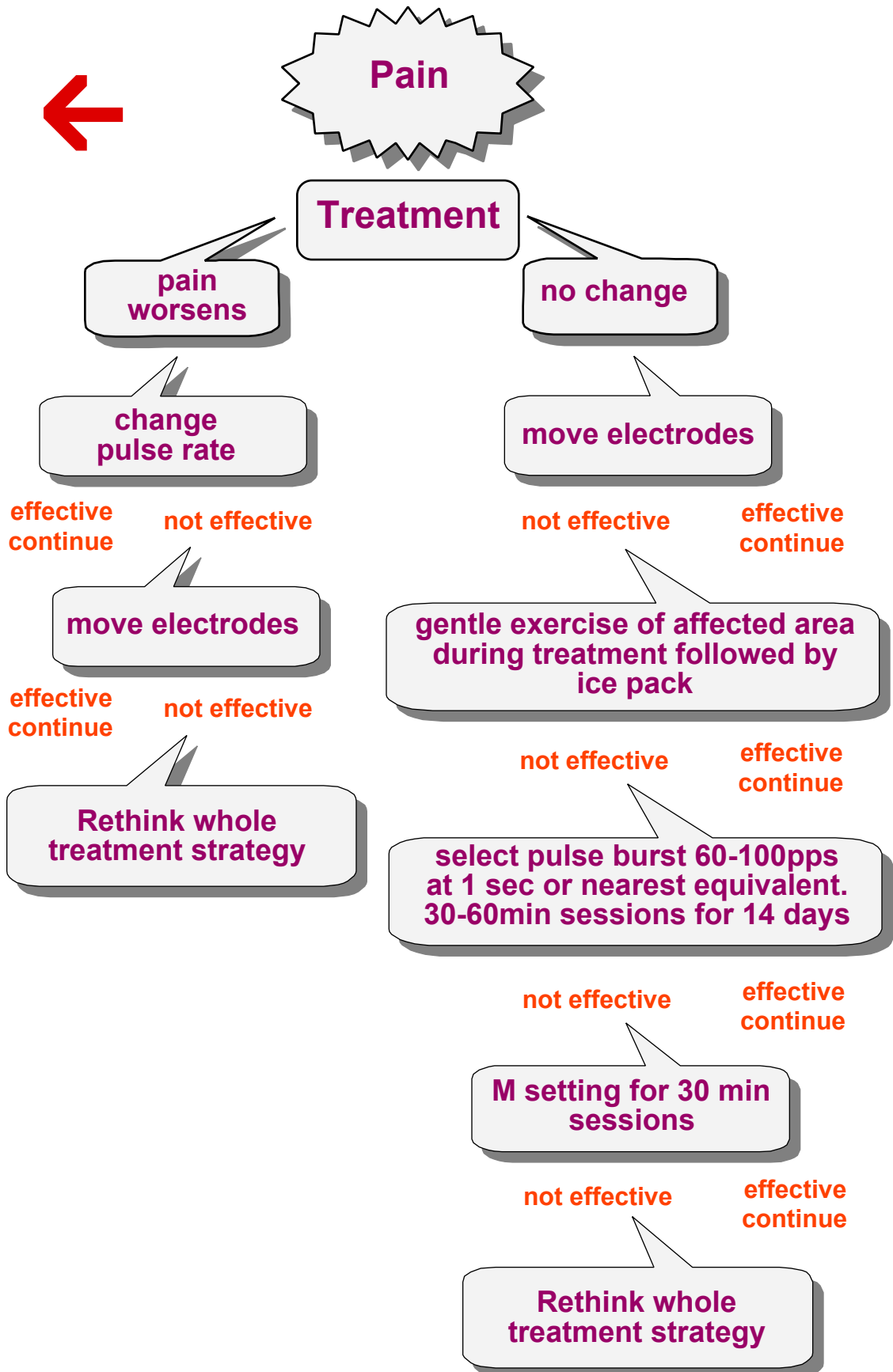
60-100pps, 1sec burst for 30min, 14 days

effective
continue

not effective

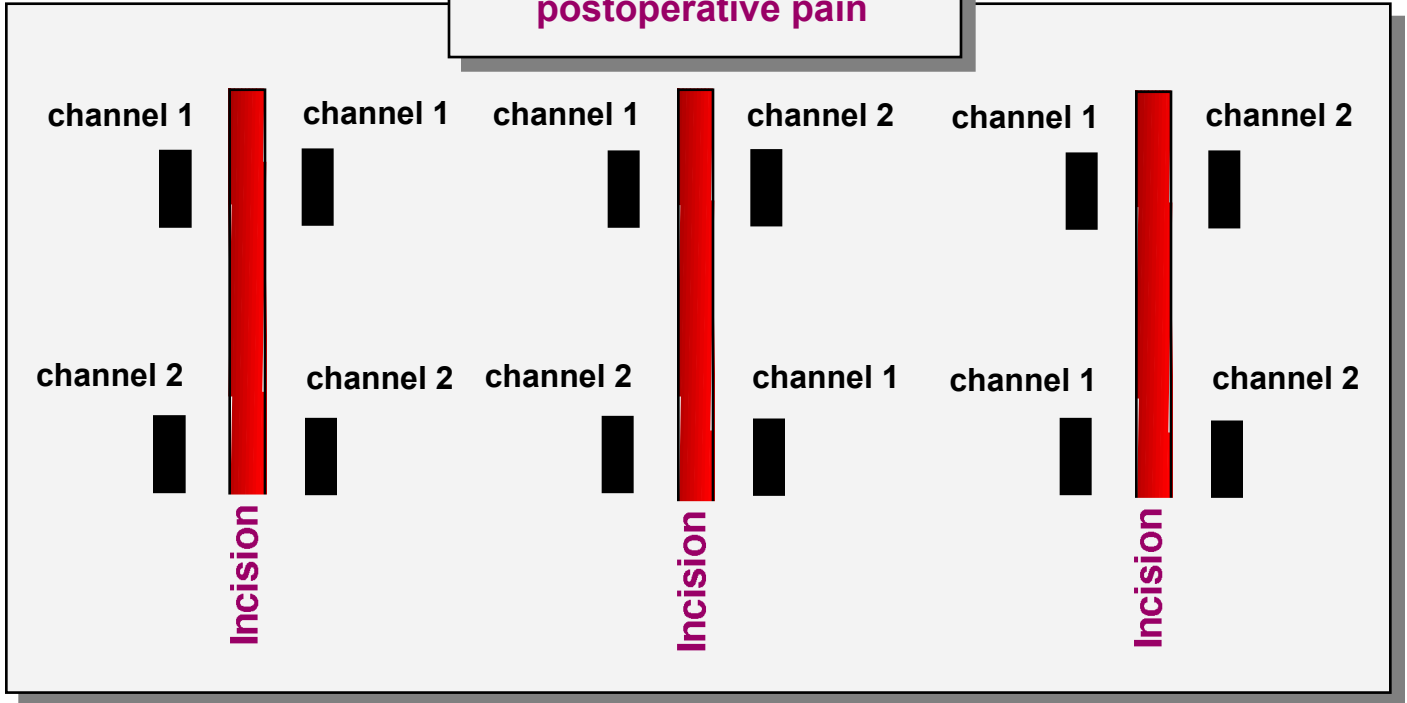
Rethink whole treatment strategy

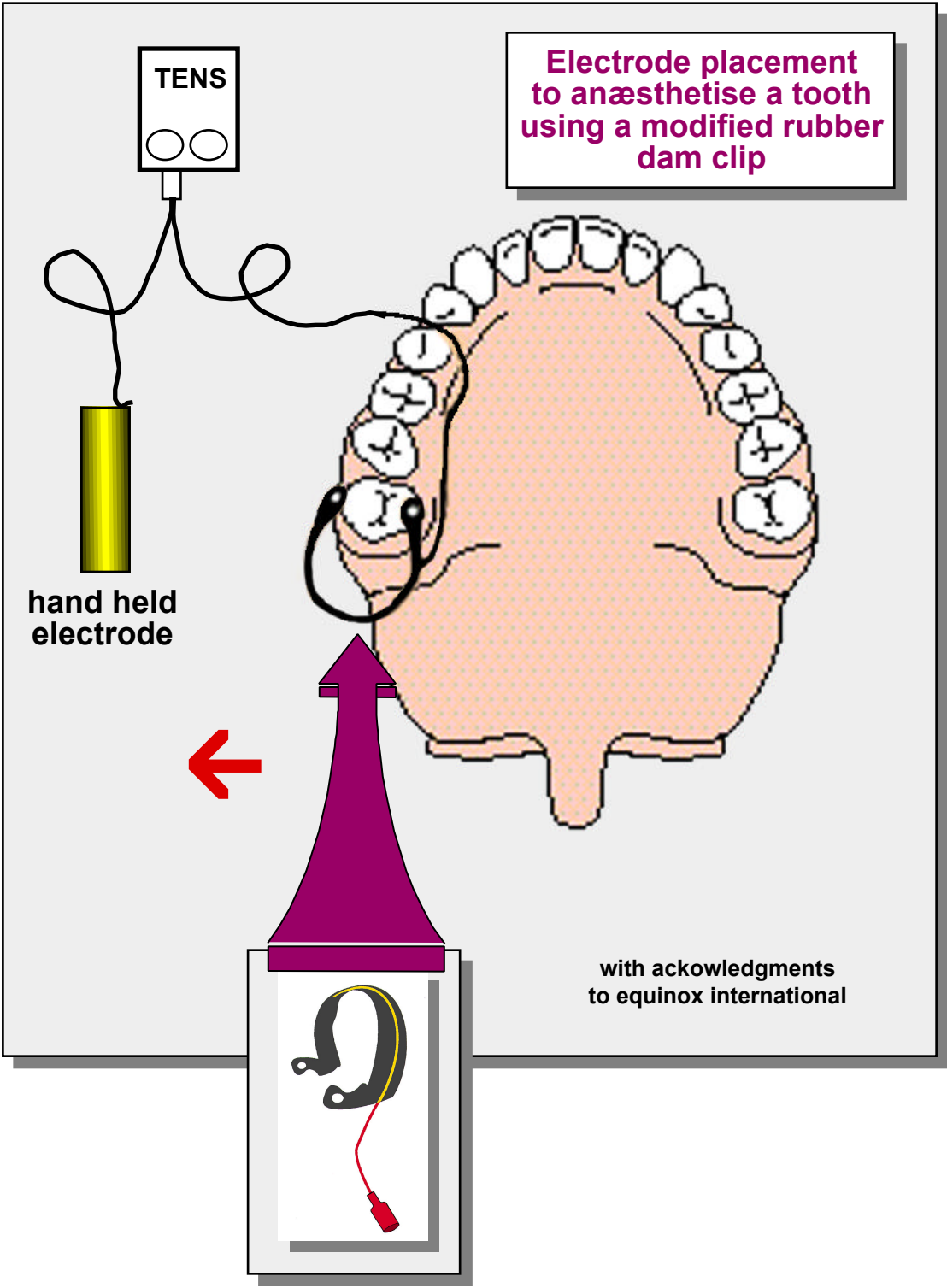
What to do next - summary





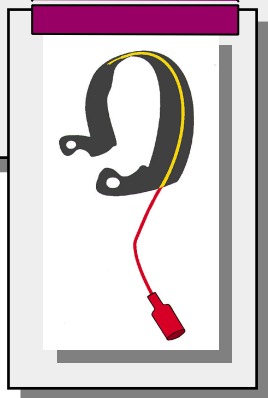
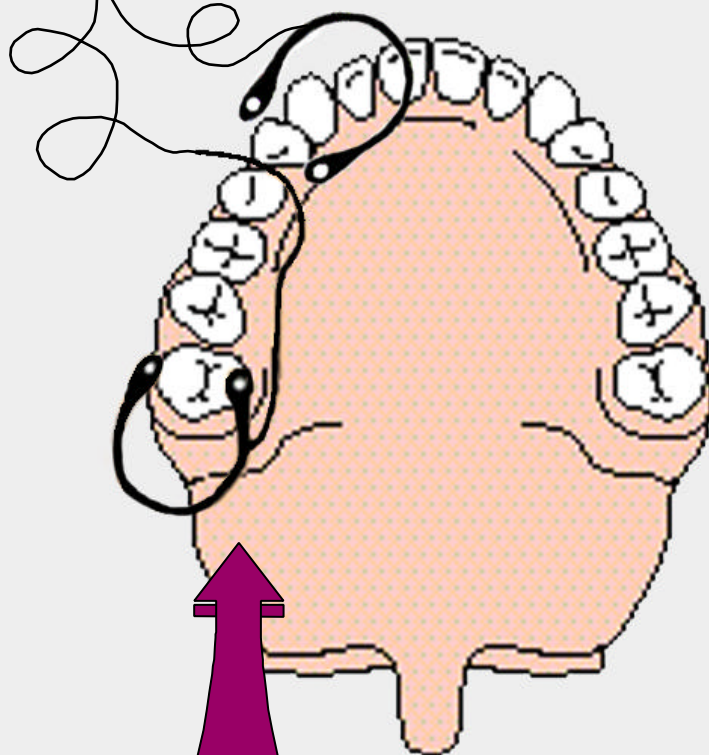
Various combinations of electrode placement for postoperative pain



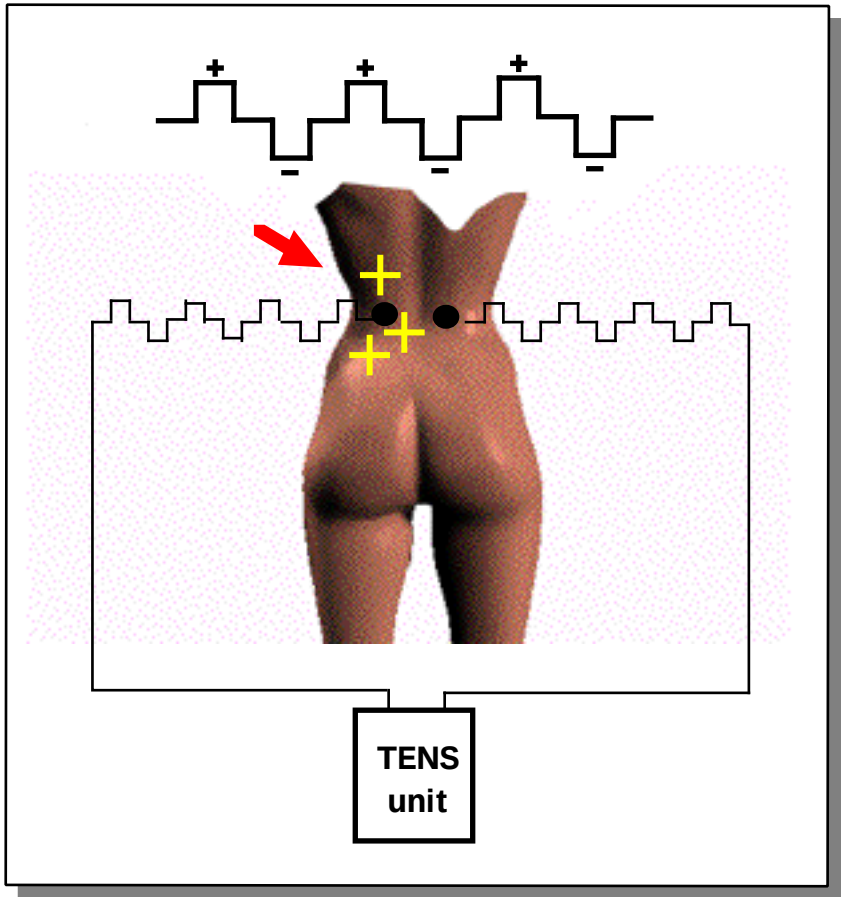


TENS

**Electrode placement
to anaesthetise teeth
using 2 modified rubber
dam clips**



with acknowledgments
to equinox international

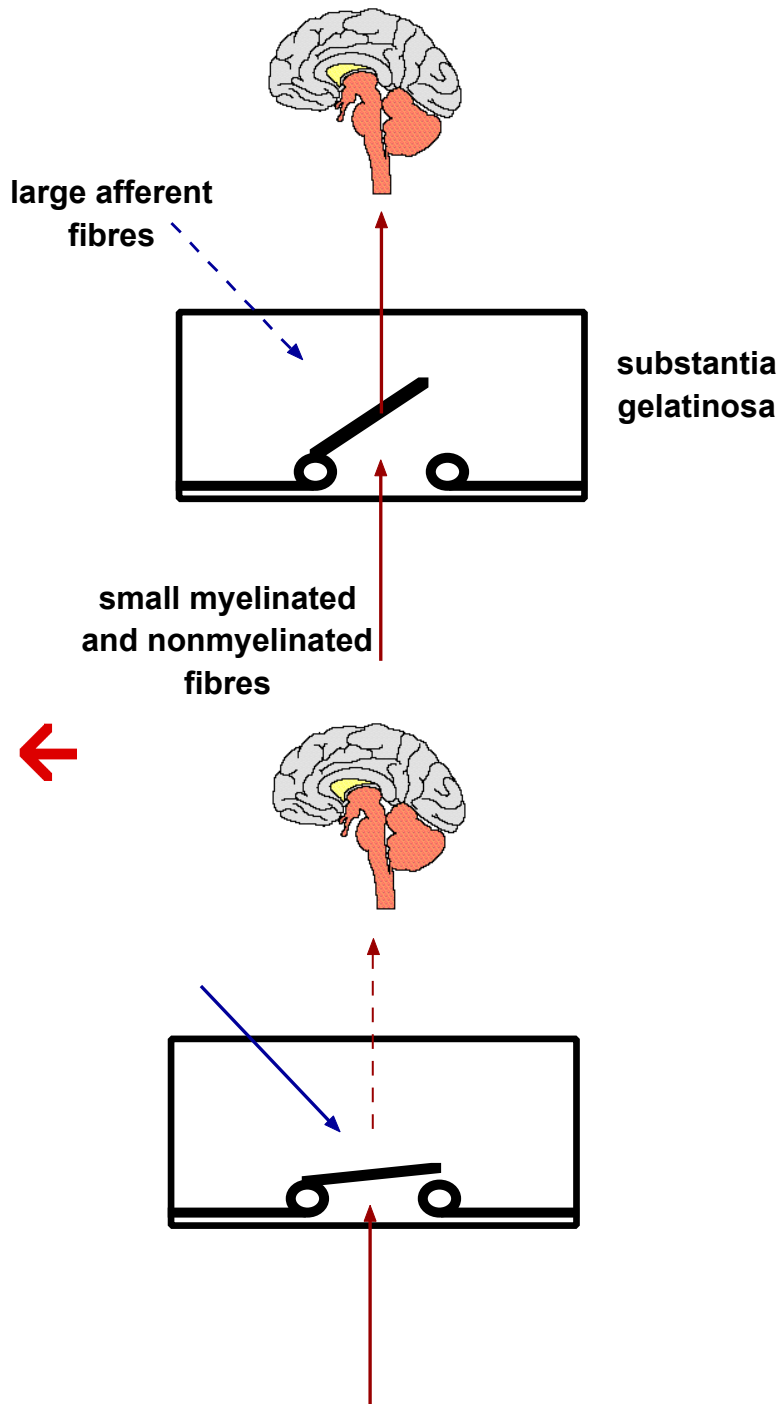


**C. Biphasic stimulation -
decreases symptoms**

Gate control theory 1

a simple summary

1. The status quo



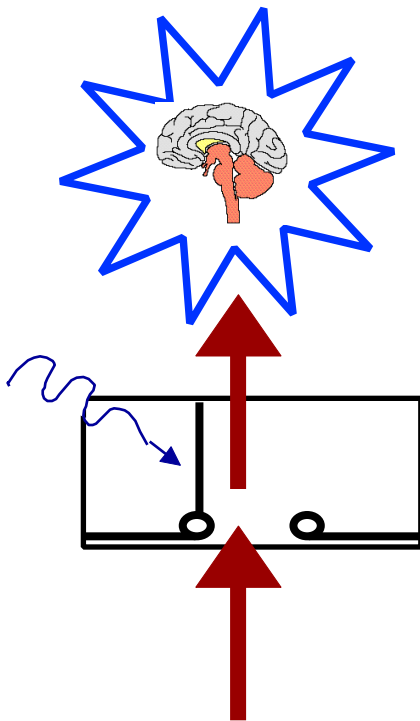
The gate is situated within the substantia gelatinosa and is held ajar by the continuous, routine maintenance input from small fibres which adapt only slowly to changes in the status quo. Large fibres are inactive.

Stimulation produces proportionally greater increase of activity from the large fibres causing the gate to start to close.

Gate control theory 2

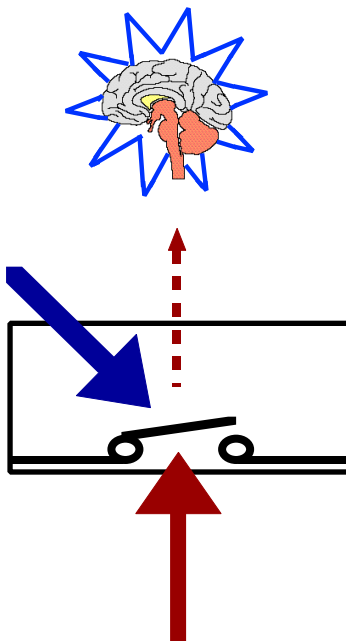
a simple summary

2. Painful stimulus



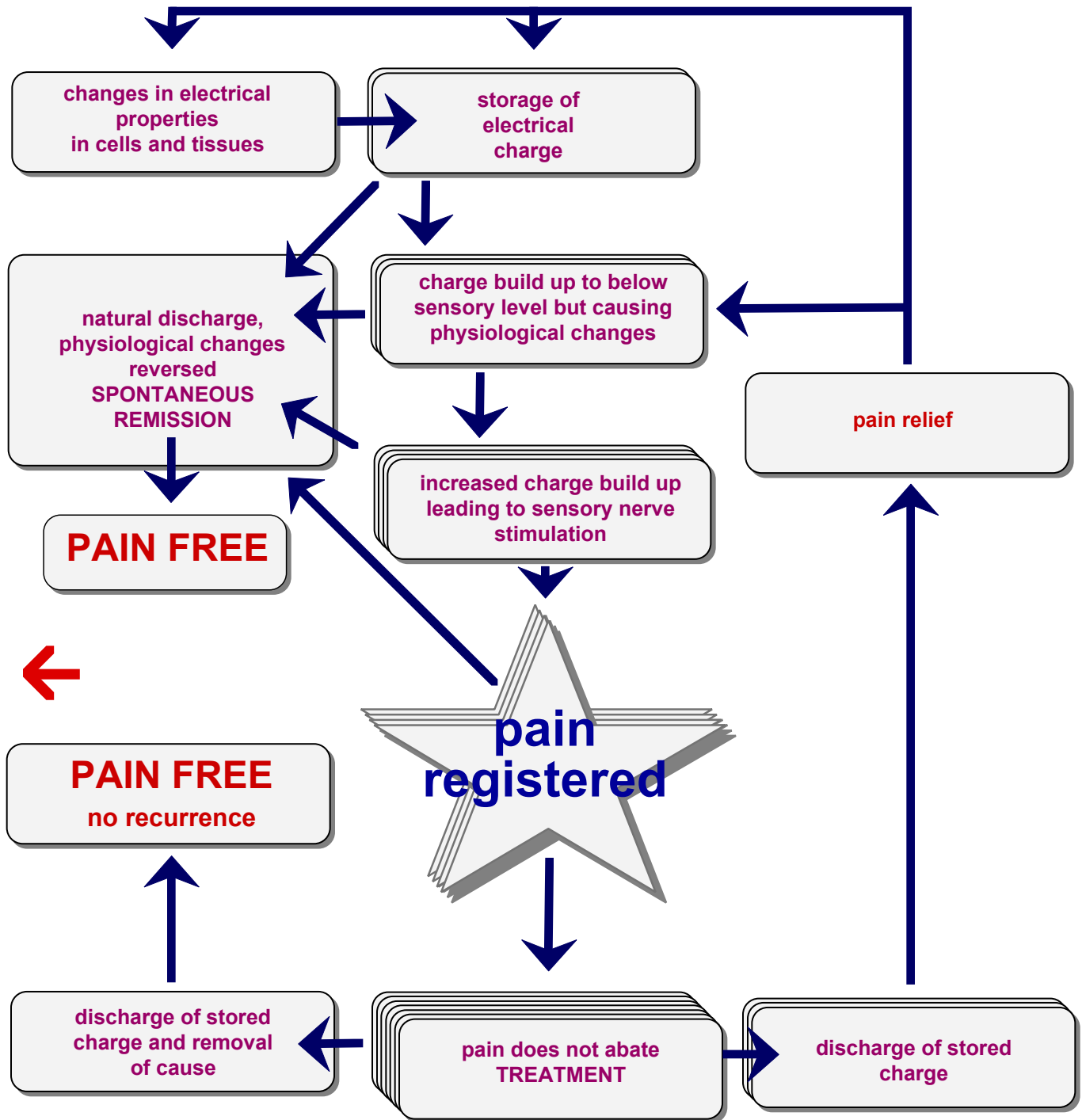
As the stimulation intensity increases input from the small and large fibres tend to cancel each other out. However, during prolonged stimulation large fibres adapt and the proportion of stimulation from the small fibres increases thereby opening the gate. The stimulus is relayed to the higher centres.

4. Pain control

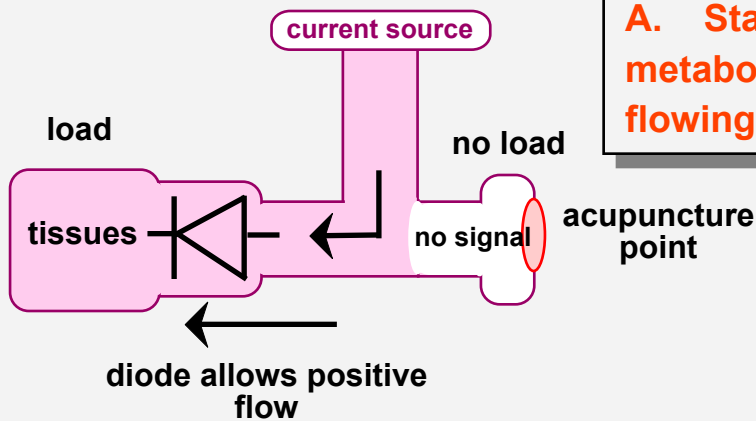


Selectively increasing the activity in large fibres, closes the gate thereby inhibiting the activity of small fibres in some parts of the nervous system at least. If the activity in the large fibres can be kept high, by TENS, for example, then pain can be controlled.

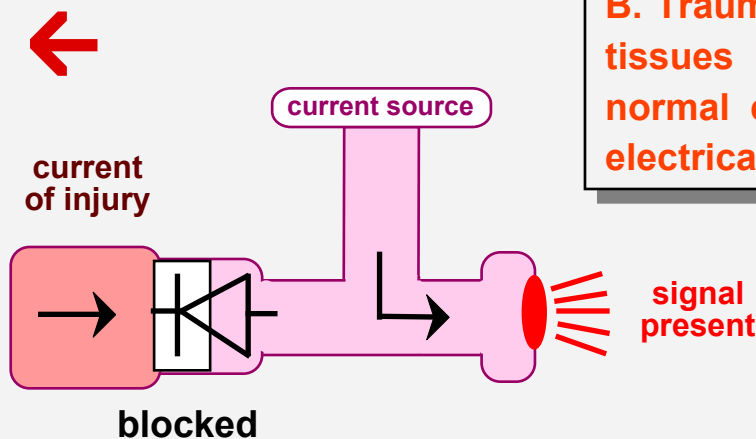
Semiconductor model for some pains and pain control



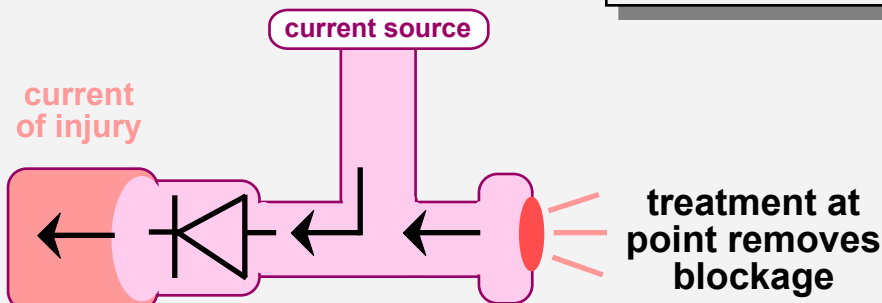
A diode gate model for pain with no obvious cause



A. Status quo: normal metabolic activity currents flowing through tissues



B. Trauma sets up current of injury in tissues blocking diode gate causing normal electrical activity to produce electrically active acupuncture points



C. Treatment at active points drives current through diode gate restoring normal activity

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